POWER

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Economies

SUPPOSING that by the invention of some new process the fuel cost of producing power could be cut in two.

What would it mean?

It would, if generally adopted, mean the saving of approximately one hundred million tons of coal per annum in the industries, hotels, theaters, office buildings and public utilities.

If it were applicable to steam railways, it would save some seventy million tons more.

But considering only the industries and utilities, the need to mine 100,000,000 less tons of coal would let out about 150,000 miners and helpers, laborers and other workers about the mines for other useful service.

Coal constitutes one-third of the freight of the railroads. One hundred million tons is roughly one-fifth of the amount of coal transported. There would be some saving in rolling stock and labor required for this purpose.

The railroads would be out some freight, but the users of power and of the things made with it would, if the saving were passed along to the consumer, be in a corresponding amount.

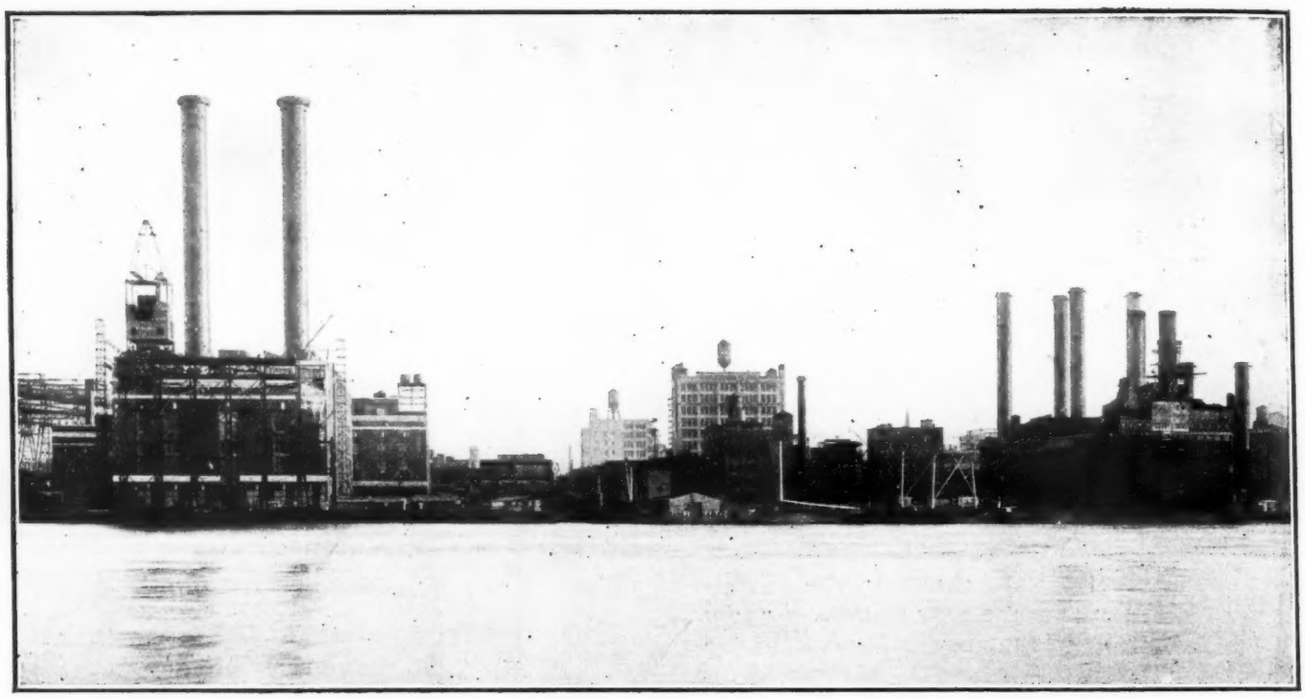
The world's work would be lessened, easier to do, and with a proper method of passing the benefit around, no one would suffer by the loss of employment or revenue, but all be better off.

If there is less work to be done, fewer men can do it, or, since all must have a chance to serve and share, the same number can do it in fewer hours per day or in fewer years out of their lifetime—a longer childhood and a toilless old age.

There can be a very considerable saving made in power costs with the means already available. There has been a steady reduction in such cost among the best practitioners, and power in the form of electric service is one of the few things available at pre-war rates.

There can be big economies effected in other directions as soon as we get over thinking that a lot of unnecessary work must be done to furnish jobs for people and as soon as business is willing to pass the savings over to the people who make them.

F. R. Low



Hudson Avenue station (first half); showing Gold Street station at extreme right

Hudson Avenue—Brooklyn Edison's Super-Station

Ultimate Capacity 400,000 to 500,000 Kw.—Present Capacity 100,000 Kw. (one group), with Another 50,000 Kw. on Order—World's Largest Condensers (70,000 sq.ft.)—Feed Water Heated by House-Turbine Condenser and Steam Bled at Two Points

SO MANY huge power projects have been initiated and carried to partial completion during the last three or four years that any new station must be extraordinary in one or more respects if it is to command attention. Whether considered as a whole or in terms of its component parts, the outstanding feature of the new Hudson Avenue station of the Brooklyn Edison Co. is size. With an ultimate capacity of 400,000 kw., and possibly 500,000 kw., with 50,000 kw. generating units—the largest yet mounted on a single shaft—and with the world's largest condensers, this station cannot fail to attract the attention of the whole engineering profession.

The reason for this super-station is to be found in Brooklyn's remarkable growth as a center of population and of industry. Of the five boroughs of Greater New York, with its total population of 5,620,000, Brooklyn is a close second to Manhattan. The figures, according to the 1920 census, are 2,284,000 for Manhattan and 2,018,000 for Brooklyn. Basing their conclusions partly on the much greater area (81 square miles) of Brooklyn, and partly on the growth curves of the two boroughs, experts on metropolitan development generally agree that Brooklyn will soon surpass Manhattan in population. At the present time it exceeds Philadelphia in size and is three-quarters as large as Chicago.

While, neglecting traction and railroad service, two utility companies, the New York Edison Co. and the United Electric Light & Power Co., furnish light and power for Manhattan Island, the corresponding service for practically the whole of Brooklyn is handled by a single corporation, the Brooklyn Edison Co. Table I shows the enormous growth (since 1918) in its power demand, which has been met up to the present time by two stations, a 65,000-kw. plant at Sixty-sixth Street and New York Bay, and the 125,000-kw. Gold Street station on the East River, east of the Manhattan bridge. In 1921 an extensive program of development was laid out, it having become evident that the combined capacity of the two existing stations would soon be exceeded by the rapidly growing load. At the same time arrangements were made for a 50,000-kw. emergency tie with the Hell Gate station in the Bronx. One of the major features of this development was the erection of a super-station, the engineering plans for which were made under the supervision of the technical staff of the Brooklyn Edison Co., with Thomas E. Murray, Inc., the designers of Waterside, Sherman Creek, Hell Gate and other large stations in the metropolitan district, as consulting engineers.

The location selected is on the East River at Hudson Avenue, east of the Gold Street station and southwest

of the Williamsburg Bridge. The Brooklyn Navy Yard adjoins the site on the east, while the skyscrapers of lower Manhattan lie diagonally across the river to the west. This site, which was cleared by dismantling an old plant of the Brooklyn Union Gas Co., was practically the only one available near the heart of Brooklyn's manufacturing center, and combining sufficient size with the presence of a suitable circulating-water supply.

TABLE I—GROWTH OF BROOKLYN EDISON LOAD FROM 1918 TO 1923

Year	1918	1922	1923
Station output, million kilowatt-hours	282	493	573
Station capacity, thousand of kilowatts	105	190	190
Maximum demand, thousands of kilowatts	86	165	180
Pounds of coal per kilowatt-hour	2.60	1.89	1.85
Kilowatt-hours sold per capita of Brooklyn	113	181	204

Fine sand with a substratum of quicksand made foundation conditions far from ideal, but the other advantages of this site more than counterbalanced this negative factor.

Bedrock being about 80 ft. down, too far to be economically reached by foundations, it was decided to erect the plant on a thick mat of reinforced concrete supported on piles driven to refusal on 2½ to 3-ft. centers over the entire building area. The foundation conditions, as will be shown later, were a determining factor in the arrangement of the plant.

The ultimate capacity of 400,000 kw. was fixed by the size of the plot, while an initial installation of at least 100,000 kw. was rendered necessary by the rate of growth of the load.

The station is laid out on the group system, which simplifies operation, increases reliability and makes possible the adoption of improvements available as successive sections are erected. Each group has two main generating units of 50,000 kw. capacity and one house turbine. Grab buckets and coal cars are used for fuel handling, while the ash is removed by sluicing.

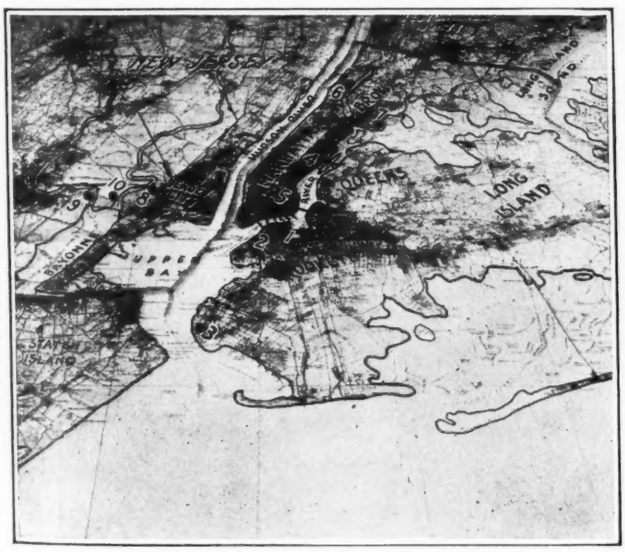


Fig. 1.—Bird's-eye map showing principal central stations in metropolitan district

Brooklyn Edison Co.—(1) Hudson Avenue, 400,000 kw. (ultimate); (2) Gold Street, 125,000 kw.; (3) Sixty-sixth Street, 65,000 kw.
New York Edison Co.—(4) Waterside (Nos. 1 and 2), 350,000 kw.; (5) Projected station, 500,000 kw.
United Electric Light & Power Co.—(6) Sherman Creek, 150,000 kw.; (7) Hell Gate, 350,000 kw. (ultimate).
Public Service Corporation—(8) Marion, 100,000 kw.; (9) Essex, 150,000 kw. at 80 per cent load factor; (10) Kearny (projected), 328,000 kw. at 80 per cent load factor.

Other features of the Hudson Avenue plant are: The use of eight boilers per generating group; the location of the boiler room next to the river; a group heat-balance system comprising a house turbine operating at 25-in. vacuum and two closed bleeder heaters on each main turbine.

There were good reasons for these features. For example, the unstable character of the soil made it desirable to place the turbine room inshore where the foundations of its more delicate equipment would have a firmer footing. Even in this location a 10-ft. thick mat of reinforced concrete was considered necessary to bridge the circulating tunnels and distribute the enormous weight of the units, while that for the boiler room was 7 ft. thick.

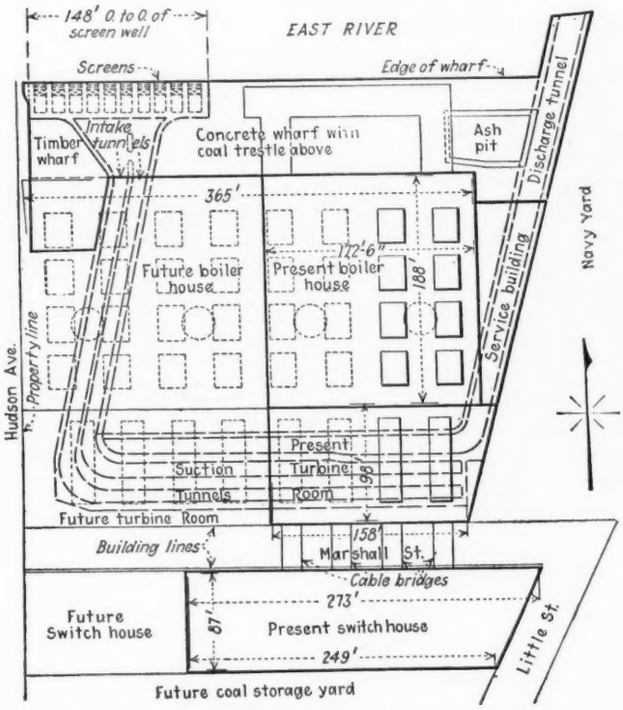


Fig. 2.—Diagram showing layout of station

Future installation shown in dotted lines.

The laying of the foundation was a difficult engineering undertaking, as was the construction of the circulating-water tunnels (see Fig. 3). The latter consist of twin intake tunnels, each 11 ft. wide and 18 ft. 8 in. high and a discharge tunnel 15 ft. wide by 18 ft. 8 in. high, the intake tunnels being built with a common bell-shaped inlet large enough to accommodate ten traveling screens. The construction of these tunnels in sand of a fluid nature presented a unique engineering problem, the solution of which required the use of extensive cofferdams of interlocking sheet-metal piling, a preliminary tremie-concrete layer to prevent sand "boils," the development of special methods of pile driving, etc.

Units of 50,000 kw. were chosen as the largest available of known reliability and compact single-shaft construction. Unit No. 1 of the first group is a single-cylinder impulse machine and No. 2 a tandem-compound reaction. The house turbine is of the reaction type and has a capacity of 4,500 kilowatts at a load factor of 75 per cent.

The heat-balance system typifies the advance of the art during the last two or three years. The rapid

development of power-plant practice is well illustrated by the fact that further refinements are being considered for the second group, part of the equipment for which has already been ordered. More will be said of the heat balance later.

With the turbine size fixed at 50,000 kw., the considerations determining the choice of 100,000 kw. as the group size were as follows: This capacity filled the present need; at the estimated rate of load growth it allowed for the timely incorporation of engineering improvements in the erection of successive sections; more than two turbines per group would have increased this period unduly; a group of this size is easily handled; everything else, the prime requisite. It was felt that extraordinary pressures and superheats would necessarily involve a certain, although perhaps minor, experimental element at the present time, and hence could not be justified at this particular time and location. Powdered fuel was also considered. The decision not to use it was based mainly on the preceding considerations as

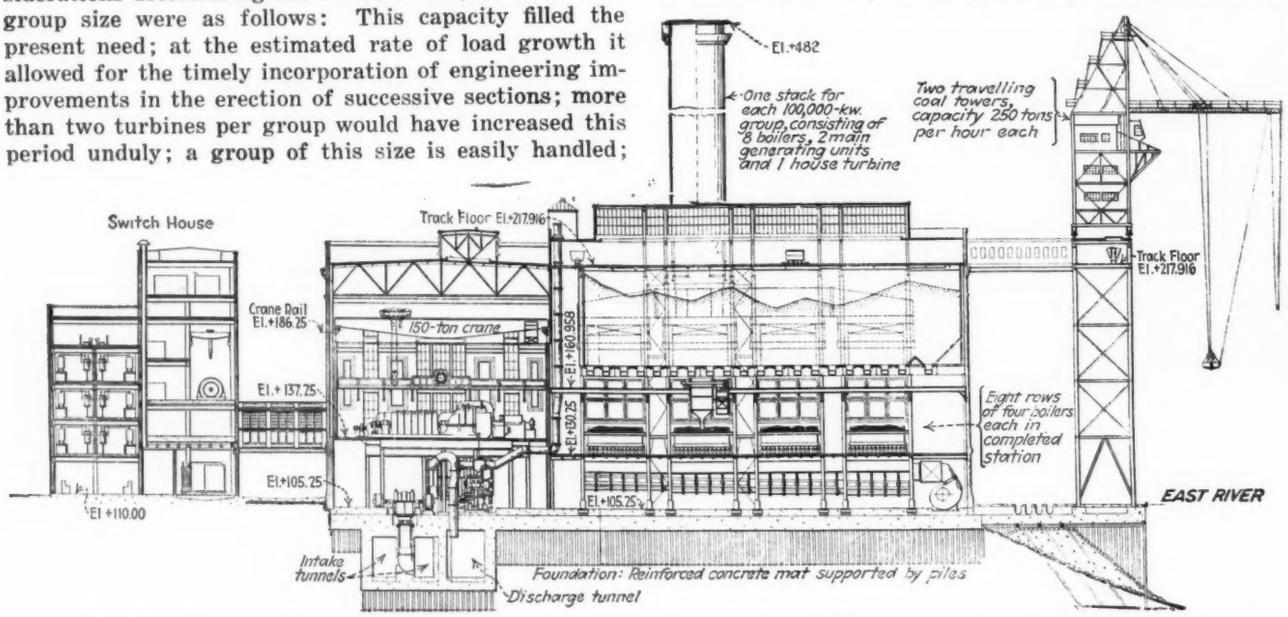


Fig. 3.—Cross-section of Hudson Avenue station showing foundation mats of reinforced concrete supported on piles

the necessary boiler capacity is about all that can be accommodated by one stack, while two stacks per group would have increased the plant cost. Fewer than eight boilers (that is, six or four) would have increased the disturbance when one boiler was taken off the line for cleaning or repairs. This fixed the size of the boilers after the group kilowatt capacity had been decided upon.

In view of the fact that steam pressures and temperatures around 500 lb. and 700 deg. have been selected for a number of new plants, and that this will undoubtedly improve the efficiency, it is reasonable to ask why the designers of Hudson Avenue fixed upon steam conditions of 285 lb. and 618 deg. To get the answer one must step outside the station and consider the problem that faces the Brooklyn Edison Co. as the sole manufacturer and distributor of electrical energy for a huge and densely populated area. Reliability is, beyond well as the fact that the distance from the coal mines and the resulting importance of transportation charges militated against the use of low-grade fuel. The high-grade fuel normally used in this district because of high transportation charges, burns with good efficiency on underfeed stokers.

It should be understood, however, that neither the question of high pressures and temperatures nor that of burning pulverized fuel is considered as closed. As successive 100,000-kw. sections of the station are erected, the designers will feel free to incorporate such engineering improvements as experience shows to be warranted for the particular location and governing conditions. In this connection it is of interest to note that the present equipment has been so designed as to permit the use of somewhat higher pressure and superheat, should it be deemed desirable.

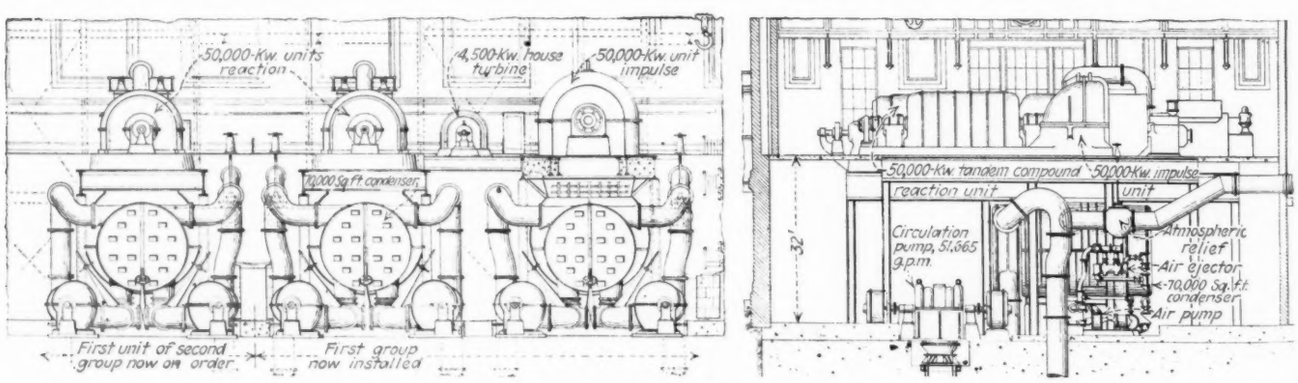
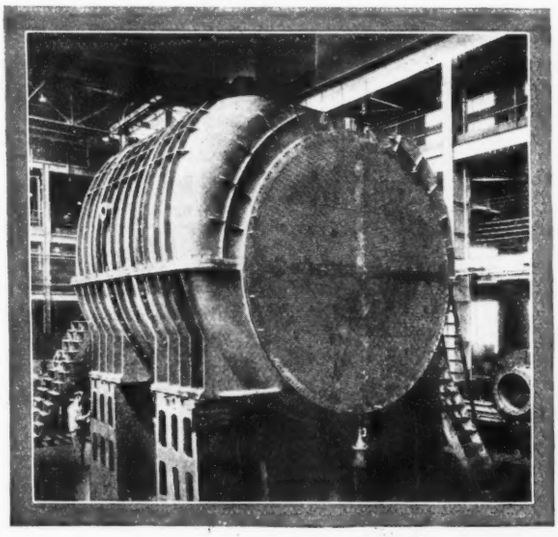


Fig. 4.—Turbines and condensers installed and on order



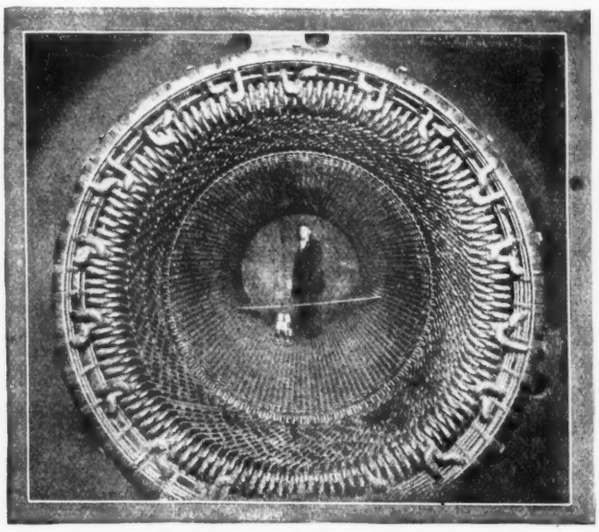


Fig. 5 (upper left)—Shop view of 70,000-sq.ft. condenser—the largest ever made

Fig. 6 (upper right)—Interior view of stator of 62,500 kva. generator

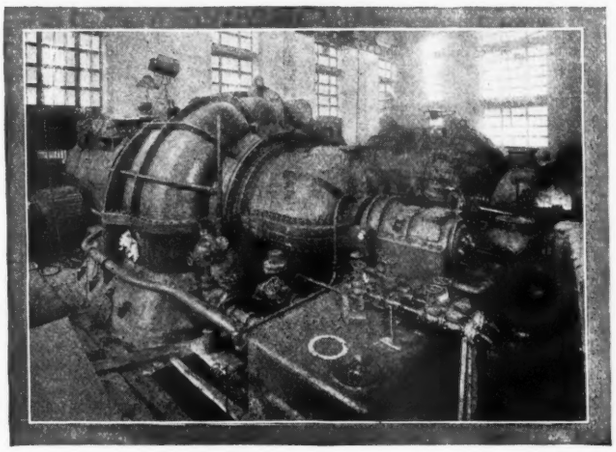
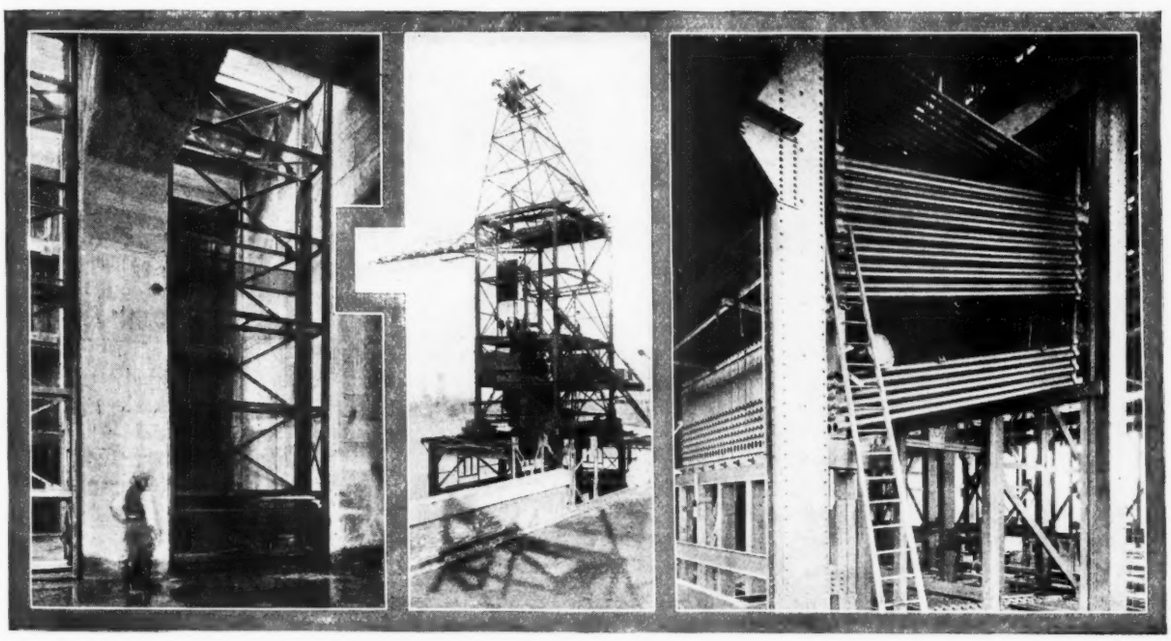


Fig. 7 (center)—First two 50,000-kw. units nearly ready for operation. In the foreground single-cylinder 21-stage unit, with tandem-compound reaction unit beyond

Fig. 8 (lower left)—Revolving screen 10 ft. wide and 30 ft. high in circulating-water intake.

Fig. 9 (lower center)—Traveling coal tower handles 250 tons per hour.

Fig. 10 (lower right)—The boilers, of double-deck cross-drum construction, have 19,650 sq.ft. of heating surface and 14-retort stokers.



Economizers were considered, but careful analysis indicated that they fell just outside the economic line with safe economizer feed temperatures and present fuel prices and load conditions. While space has been provided for their later installation if desired, the installation of economizers in the first group is not likely, as it would necessitate a change in the bleeder-heater arrangement which now supplies the boilers with water

be of interest to follow through in a more orderly fashion the flow of fuel, steam and water in the main plant cycles, and in passing touch upon the more important features of the apparatus involved.

Coal, arriving at the station by barges or ocean-going ships, is lifted by the grab bucket of one of two 250-ton traveling coal towers to a single-roll crusher in the tower. The towers roll on 25-ft. gage tracks about

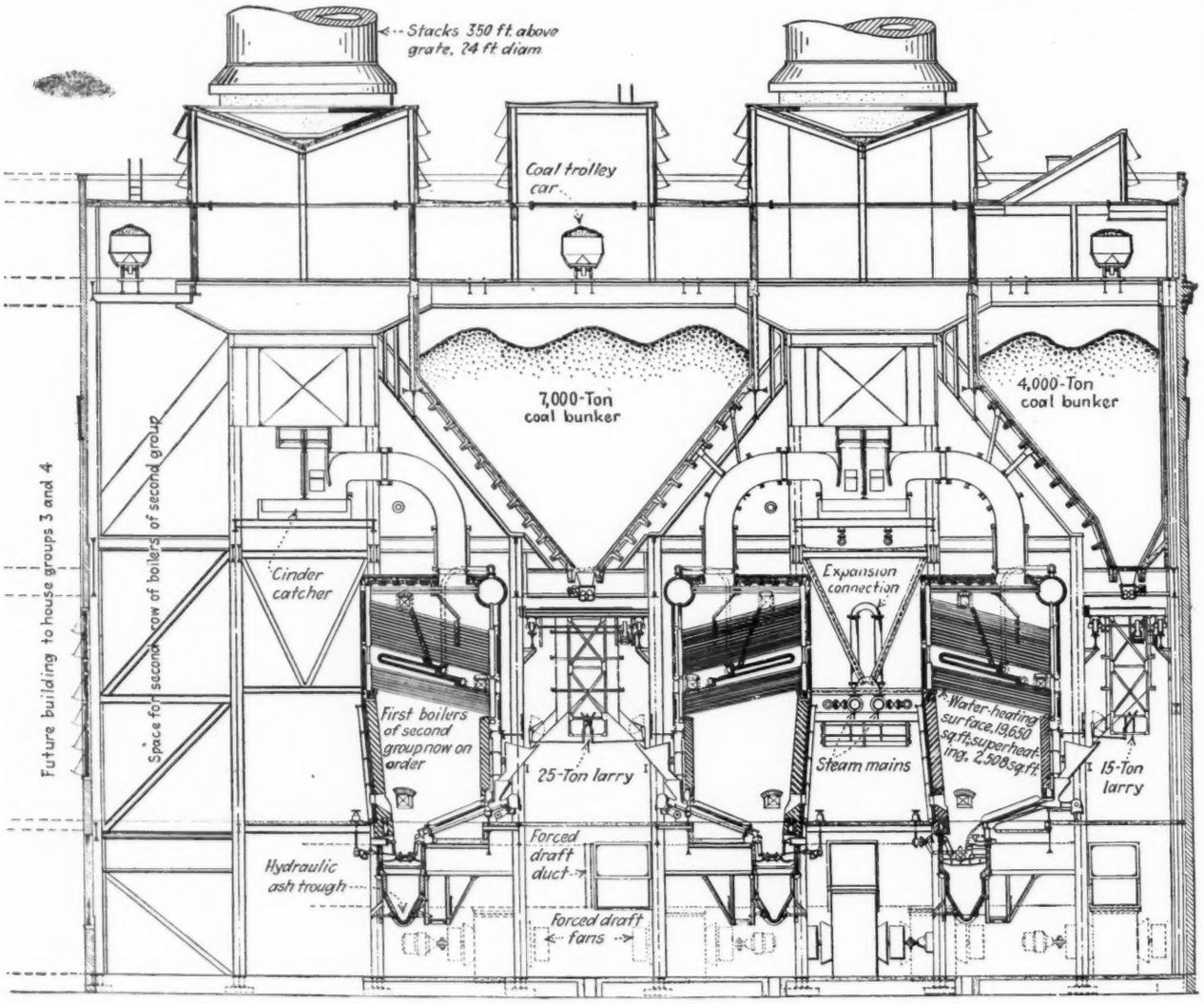

Stacks 350 ft above grate, 24 ft diam
Coal trolley car
7,000-Ton coal bunker
4,000-Ton coal bunker
Future building to house groups 3 and 4
Space for second row of boilers of second group
Cinder catcher
Expansion connection
First boilers of second group now on order
25-Ton larry
Steam mains
Water-heating surface, 19,650 sq.ft.; superheating, 2,508 sq.ft.
15-Ton larry
Hydraulic ash trough
Forced draft duct
Forced draft fans

Fig. 11.—Cross-section of present boiler room (half of ultimate)

at 285 deg. This objection would not apply in the case of flue-gas air preheaters.

The extraordinary bunker capacity of the plant (29,900 tons for the ultimate 400,000 kw.) is explained by the fact that no land is available for coal storage near the plant. The bunker capacity could run the plant for about ten days at an average output of 50 per cent capacity. To take care of coal shortages of greater duration, a 200,000-ton storage yard has been provided at Rossville, Staten Island, twenty-five miles away. Considering all fixed charges on the investment in land and coal-handling equipment and the charges for labor, coal depreciation, etc., the storage cost is not considered too high a premium to insure continuous service to the community in case of a coal shortage.

With this general review of the engineering principles underlying the high spots of the design, it will

125 ft. above the river. Reduced to a maximum of 2-in. lumps by the crusher, the coal falls into 5-ton trolley cars on a track parallel to the river and straddled by the legs of the tower.

The cars, dispatched in pairs or singly, pass over an automatic weigher to various branch tracks running over concrete-arch sectionalized bunkers which extend the whole length of each firing aisle. The cars are manually dispatched, but operate automatically at a speed of 200 ft. per min. They are dumped and closed by blocks along the track.

Entering one of the furnaces through its 14-retort underfeed stoker, the coal is consumed at a maximum rate of about 13 tons per hour per furnace, combustion being carried on in a space 21 ft. high (to uptake header) and 7,500 cu.ft. in volume. The gases pass over 19,650 sq.ft. of 4-in. boiler tube, the boiler being

of the cross-drum double-deck type, with the lower deck of six rows exposed to the radiant heat. The superheater is between decks. Leaving the boiler, the gases pass through a cinder catcher with flowing water, and thence to the stack.

The ash, after being broken up in the clinker grinder, falls into a sluiceway and is washed down by water streams to a riverside ashpit, whence the water escapes over a weir, while the ash is removed to scows by a special locomotive crane.

Starting once more at the boiler, the steam, generated at 285 lb. and 200 deg. superheat, passes through stop and check valves and sectionalized headers to the main turbines and house turbine, some being bled off from the main units, as explained later.

On account of their enormous size among other features, the main generating units, with their condensers, are worthy of a fairly complete description. They will, therefore, be the subject of a later article, no attempt being made to go into their details in the present article.

Steam exhausted from either of the main units at a vacuum around 29 in., passes to its 70,000-sq.ft. condenser, the largest in the world. Here it is condensed by circulating water supplied by two pumps of approximately 50,000 gal. per min. capacity each. Division of the condenser into two vertical halves with independent circulating pumps permits operating either half of the condenser while the other half is being cleaned. A cross-connection allows either half to be supplied with cooling water by either one of the circulating pumps. As an additional precaution the two circulating pumps receive their water from two different intake tunnels.

While the heat-balance diagram, as shown in Fig. 12, may at first seem rather complicated, it will prove, when studied, to be fundamentally simple and easily described in a few sentences. To trace out the heat-balance arrangement for the first group, one should start with the two streams of condensate at about 80 deg. from the 70,000-sq.ft. condensers. These streams pass through the intercoolers and after-condensers of the respective air ejectors. The two streams then unite to pass as circulating water through the 4,000-sq.ft. surface condenser of the house turbine, which they leave (at three-quarters load) at 117 deg., having maintained a vacuum of about 25 in. on the house turbine. After passing through the boiler feed pumps, the stream again divides, one branch going to the closed bleeder heaters of each main unit.

The heaters are all alike, heavily constructed of steel with seamless copper U-tubes and steel shells. Some idea of the heavy construction required, that these heaters may safely withstand the boiler pressure under which they operate, may be gained from the fact that the Muntz-metal tube sheets are 4 in. thick. Each heater has 3,500 sq.ft. of tube surface. Those on the 21-stage impulse unit take steam from the tenth and sixteenth stages, while those on the reaction turbine are supplied with steam bled from the exhaust of the high-pressure cylinder and from the entrance of the double-flow section of the low-pressure cylinder. The

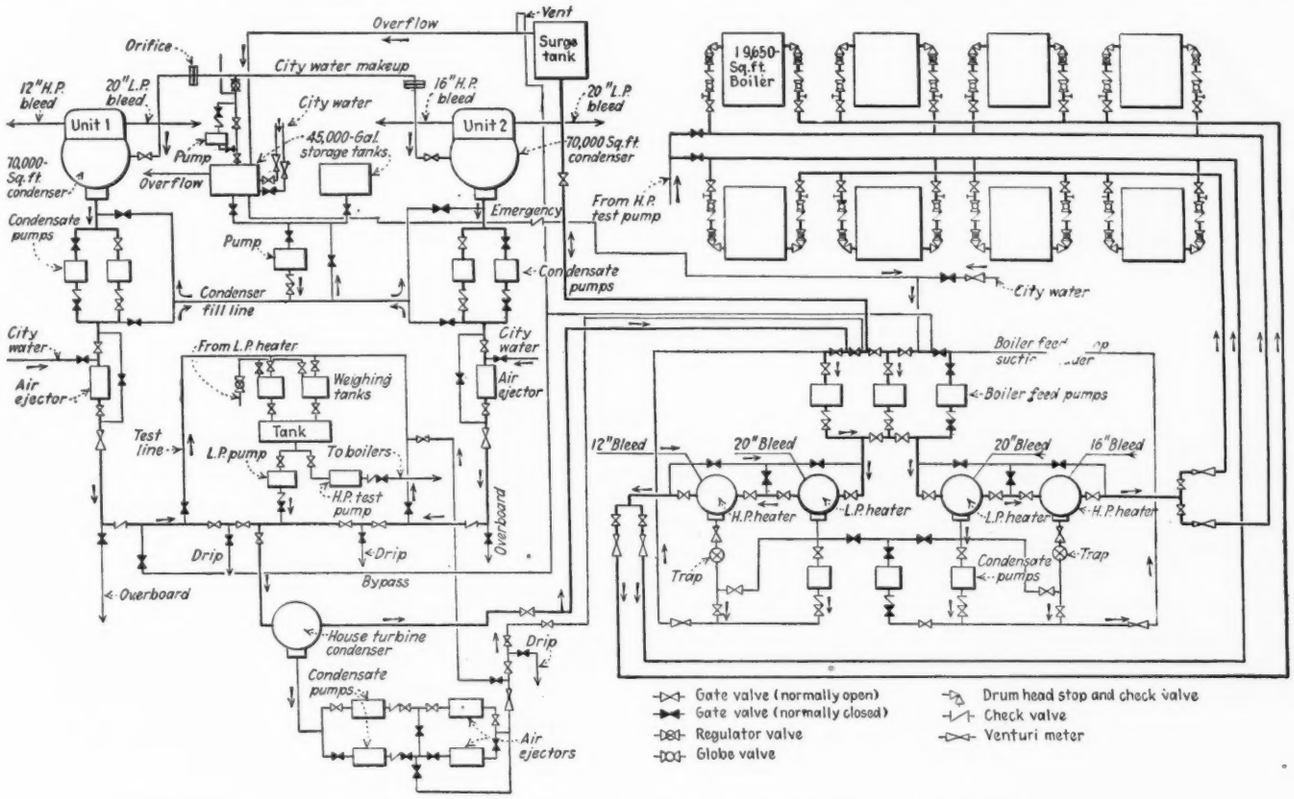


Fig. 12.—Feed-water diagram for one group showing heat-balance and testing connections

TABLE II—GUARANTEED WATER RATES OF MAIN UNITS AT 280 LB. ABS., 200 DEG. SUP. 29-IN. VACUUM

Load, Kw.	Unit No. 1 (Impulse), Lb. per Kw.-Hr.	Load, Kw.	Unit No. 2 (Reaction), Lb. per Kw.-Hr.
20,000	11.05	25,000	10.48
30,000	10.40	36,000	10.10
40,000	10.05	45,000	10.25
50,000	10.45	50,000	10.44

corresponding absolute pressures are about 55 lb. and 10 lb. for both units at three-quarters load, each pair of heaters raising the water temperature from 122 deg. to 285 deg. approximately.

In the event of damage to the heaters, the bleeder valves automatically close. The lower stages of the turbines are designed to take care of the additional steam passing to the condenser.

It will be noted that, except for the somewhat lower

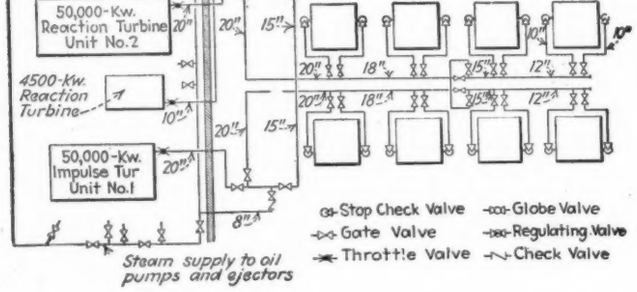


Fig. 13.—Diagram of main steam lines of one group

efficiency ratio of the house turbine, this layout is thermally equivalent to a heat-balance system without a house turbine, but bleeding the main units at three points instead of two. In other words, if the house turbine could use steam as effectively as the main unit, it would make practically no difference whether the first stage of feed-water heating was accomplished by the house-turbine exhaust at 25-in. vacuum or by steam bled from the main unit at the same pressure. The fundamental reason for the installation of a house turbine was to furnish an additional source of auxiliary power, but its proper connection into the heat balance was necessary to secure this result at the lowest fuel cost.

The use of bleeder heaters adds very little to the complexity of the station. No regulation is required for the amount of steam bled, this being automatically determined by the temperature and pressure conditions corresponding to the load carried. It is evident that the amount of steam consumed by a bleeder heater can never exceed that required to heat the feed water to a point somewhat below the existing saturation temperature of the bled steam.

The installation of bleeder heaters had little effect on the cost of the station per unit of output. For one thing, the 7,000 sq.ft. of surface in each pair of heaters reduced the necessary surface in the main condenser by about 4,000 sq.ft. It is true that the cost of heater surface was necessarily higher than the same amount of condenser surface, on account of the high-pressure construction. But this greater cost per square foot, and the fact that only about 60 per cent of the heater surface is saved at the main unit condenser, is counterbalanced by a reduction in size of all the steam generating equipment due to the increased efficiency of the station. This saving shows up in the boilers, stokers, coal-handling and storage equipment, chimney size, etc.

In addition to the surge tank each group is provided with two 45,000-gal. storage tanks, from which in emergency city water may be added as needed to the condensate leaving the main condenser.

The importance of periodic performance tests was realized by the designers, who have installed permanent testing equipment, piped into the system so that the feed water can, by the turning of a few valves, be sent through a weighing-tank system and delivered at will to the house-turbine heater circuit or directly to the boiler.

To reduce the fire hazard and eliminate air-washing, the generator cooling air is passed through cooling coils and recirculated. On account of its low temperature this heat has a very small valve for heat-balance purposes, and so no attempt is made to recover it. Because of the extreme importance of the generator air cooler to continuity of service and the difficulty of keeping the $\frac{5}{8}$-in. tubes clear with river water, artesian wells have been provided for this specific purpose.

The auxiliary power is supplied at 2,300 volts three-phase 60-cycles, at 440 volts three-phase 60 cycles and at 250 volts. With the exception of the boiler auxiliaries (not including the feed pump) all main auxiliary motors above 50 hp. are operated from the 2,300-volt bus. To insure continuity of operation, this bus is supplied from three independent sources, comprising one connection to the Gold Street station through a frequency changer, one connection to the house turbine, and one to the main bus through house transformers. The three sources of power are so connected to the bus, and the bus itself is so sectionalized, as to insure maximum continuity of service.

To insure operation at a vital point, each group of eight boilers is supplied with three boiler-feed pumps,

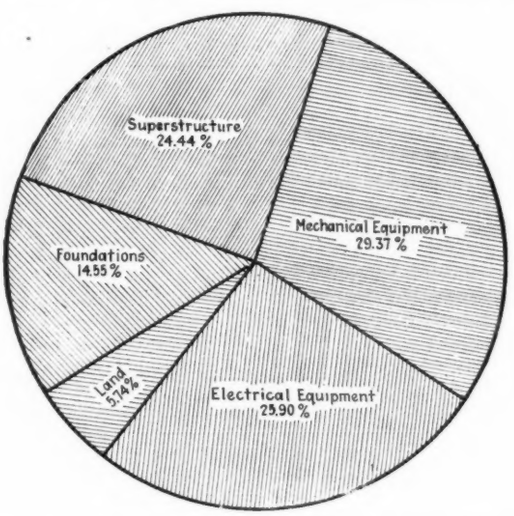


Fig. 14.—Distribution of costs at Hudson Avenue

Land is for completed station, building and foundation for half of station, and equipment for three-eighths of station. Generators included with electrical equipment.

any two of which are capable of carrying the maximum load. Two of these are motor operated, while the third (a spare) is turbine driven. In the same way either of the two motor-driven circulating pumps on the main condenser is capable of carrying practically full turbine load at a slightly reduced vacuum. This, together with the fact that the two pumps draw water from separate tunnels, practically insures the continuous operation of the condensers.

The station was laid out with the expectation of

installing centralized combustion control. For this reason the stokers, clinker grinders and forced-draft fans are driven by direct-current motors fed by a special motor-generator set with several generators. The Ward-Leonard system is used to vary the generated voltage and hence the speed of all motors for a given service.

Excitation for the main units is assured by three sources of supply—a direct-connected exciter on each unit, a storage-battery excitation bus and two 500-kw. motor-generator sets for the whole station.

The Hudson Avenue station is tied in with the near-by 25-cycle Gold Street station by a 35,000-kva. frequency changer operating at 300 r.p.m. This unit is 49 ft. long, 21 ft. wide and 14 ft. high and weighs 886,000 lb.

The instrument equipment of the station is unusually complete, permitting a careful check on operation at all times. Instruments are so located that independent tests may be made of boiler-room and turbine-room operation, while complete heat-balance data may be obtained whenever desired. Each turbine has individual flow meters, venturi meters and recording gages for steam pressure and temperature and for vacuum.

Alongside of each boiler is a panel containing two boiler meters, indicating steam-pressure gages showing the pressure at the drum and superheater outlet, triplex draft gages and air-duct pressure recorders. Drum controllers for the stokers and clinker grinders are mounted on benches beneath the instrument panels.

Mention has already been made of the motor-generator set providing group speed control for the direct-current-operated boiler auxiliaries. To allow for the future use of this system in connection with centralized boiler control, a special boiler control room for the entire station has been built at the north end of the present boiler room. This will contain a panel for each group of eight boilers and a master panel for the whole station, each group panel having a group load indicator, a steam-pressure recorder, an air-duct-pressure gage and a group stoker speed indicator. Controls and ammeters are provided for each of the forced-draft fans. A temperature recorder registers the flue-gas temperature of each boiler in the group. Boiler-feed water is measured by Venturi meters. In addition, a large number of instruments for furnishing heat-balance data are mounted on special heat-balance panels in the boiler-control room. Additional instruments and gages are located throughout the plant for the guidance of the operators. For testing the main turbines and boilers, large weighing tanks with highly accurate 25-ton scales have been installed.

PRINCIPAL MECHANICAL EQUIPMENT IN THE HUDSON AVE. STATION, BROOKLYN EDISON CO.

GENERAL

Plant Location—Foot of Hudson Ave. and East River, Brooklyn, N. Y. (west of Navy Yard and east of Manhattan Bridge).
Character of service—Light and power.
Capacity (ultimate)—400,000 kw.
Capacity (installed)—100,000 kw.
Capacity (ultimate) per square foot of turbine-room floor space—11.2 kw.
Consulting Engineers—Thos. E. Murray, Inc.

STRUCTURES

Power Plant Building, ultimate (containing boiler room and turbine room):
- Dimensions—Length, 365 ft.; width 286 ft.; height 130 ft.
- Type of construction—Foundations reinforced-concrete slab 7 ft. thick (boiler room), 10 ft. thick (turbine room), supported on piles, electrical galleries 6 ft. concrete slab without piles. Buildings of steel and brick.
- Subdivisions—Boiler room, 188 ft. wide, 365 ft. long; turbine room, 98 ft. wide, 365 ft. long.

Electrical Galleries:
- Dimensions—Length (present), 273 ft.; length (ultimate), 407 ft.; width, 87 ft.; height, 116 ft. (7 stories).
- Type of construction—Brick and steel.

Cubic feet of ultimate building (electrical galleries and boiler and turbine building) per kilowatt of ultimate capacity—44.0.
General Contractors . . . Frederick Snare Corp.

BOILERS AND SUPERHEATERS

Make of boilers—Babcock & Wilcox Co.
Type of boilers—Cross-drum, water-tube.
Number—Ultimate 32; installed, 8 (one group).
Width of firing aisles—Outside aisles, 13 ft.; Firing aisles and flue aisles, each 20 ft.
Areas and volumes per boiler—Water-heating surface, 19,650 sq.ft.; projected grate area, *F** 380 sq.ft. *W* 355.7 sq.ft.; furnace volume, 7,500 cu.ft.; superheating surface 2,508 sq.ft.
Ratios—Water-heating surface to grate surface, *F* 51.6, *W* 55.2; water-heating surface to kw. installed, 1.57; water-heating surface to boiler-room floor area (ultimate basis), 9.1; furnace volume to water-heating surface, 0.382; furnace volume to projected grate area, *F* 19.7, *W* 21.1; superheating surface to water-heating surface, 0.128.
Size of boiler tubes—Diameter (outside), 4 in.; length, 20 ft.; thickness, No. 8 B.w.g.
Drum dimensions—30 ft. 6 in. long by 54 in. diameter (1-in. thick sheet).
Tube arrangement—42 tubes wide, 20 tubes high; superheater located above bottom 6 rows; horizontal and diagonal cleaning lanes.
Boiler pressure (gage)—285 lb.
Make of superheater—Babcock & Wilcox Co.
Type of superheater—Convection, single loop.
Superheat at 200 per cent rating—200 deg. F.
Total steam temperature at 200 per cent rating—618 deg. F.
Type of boiler setting—Brick, steel-encased, single-fired.
Construction of setting—22½ in. of General Refractories Co. (Olive Hill) firebrick, 2½ in. of Sil-O-Cel insulating brick; Bernitz Blocks; settings (inside dimensions), 21 ft. 10 in. high from floor to bottom of uptake header; width, 24 ft. 8 in. Erected by Rust Eng. Co. Casings by Shevlin Eng. Co.

*F stands for Frederick Stoker and *W* for Westinghouse.

STOKERS

Number per boiler—1.
Make—2 Combustion Engineering Corp. (Frederick), 6 Westinghouse Electric & Mfg. Co.
Type—Underfeed, extension grate with clinker grinder.
Continuous capacity—10 tons per hour.
Number of retorts per stoker—14.
Drive, Westinghouse—Stokers: Individual 7/14 hp., 300/1,200 r.p.m., 240-volt d.c. shunt-wound motor, with Morse chain. Clinker grinders: 2 motors per grinder, 2/4 hp., 300/1,200 r.p.m., 240-volt d.c. shunt-wound, with Morse chain.
Drive, Frederick—Stokers: Individual, 5/17.5 hp., 300/1,200 r.p.m. shunt-wound d.c. with Morse chain. Clinker grinders: 2 motors per grinder, 6 hp., 850 r.p.m., shunt-wound d.c.
Motor control—Drum type with Ward Leonard control sets for all stokers and clinker grinders.
Fuel—Eastern run-of-mine bituminous; fixed carbon, 74 per cent; volatile, 16 per cent; ash, 8 per cent; moisture, 2 per cent; sulphur, 2 per cent.

SPECIAL BOILER EQUIPMENT

Soot blowers—Diamond Power Specialty Corp.: 22 heads per boiler.
Boiler gage glasses—Inclined glass type, made by Ernst & Co.
Other equipment listed under "Draft," "Valves," etc.

DRAFT (GENERAL)

Type—Balanced with forced draft fans.
Induced-draft fans—Not used.
Make of control—Not decided.

FORCED-DRAFT EQUIPMENT

Number of fans—4 for each group of 8 boilers.
Make and type of fans—B. F. Sturtevant Co., "Turbovane."
Fan drive—General Electric 300-hp., 600/667-r.p.m., 250-volt, d.c. shunt-wound motors, with Ward Leonard control.
Capacity of each fan—170,000 cu.ft. per min. at 7 in. pressure.

CHIMNEYS

Built by—Riter Conley Co.
Number—1 for each group of 8 boilers.
Type—Self-supporting, steel, lined full height with 4-in. radial brick (Alphons Custodis).
Size—Height above grate, 350 ft.; inside diameter, 22 ft. 4 in.

COAL HANDLING

Supply received by—Barge or ship.
Coal towers—Two, 250-ton per hr.; (rolling 50 ft. per min.) with single-roll (2-in. lump) contained crusher and 3-ton Rawson grab; hoist drive, 625-hp., 180 r.p.m., 275-volt d.c. motor; propelling motor, 60-hp., 440-volt, 3-phase, 60 cycle; trolley motor, 75-hp., 485-r.p.m., 250-volt d.c.; direct-current furnished by motor-generator set.
Handling to bunkers—10 (present) 5-ton (200 ft. per min.) automatic trolley cars running one direction only on tracks passing under towers and over each bunker; drive, 5-hp. single-phase motors. System furnished by Bergen Point Iron Works.
Bunkers:
- Make—McClintic-Marshall Construction Co.
- Type—Waterproofed reinforced-concrete arch with brick lining and motor-operated gates.
- Number and capacity—One 4,000-ton at end firing aisle of boiler room, one 6,900 ton in each remaining firing aisle; total (ultimate) capacity, 28,700 tons.
- Yard storage capacity—200,000 tons (at Staten Island).

PRINCIPAL MECHANICAL EQUIPMENT IN THE HUDSON AVE. STATION (Concluded)

Ratio tons storage capacity to ultimate kw. installed—Bunkers, 0.072; outside, 0.50.
Coal weighing—25-ton Fairbanks scale in track of coal-car system, equipped with 12-ton Streeter-Amett automatic weigher; Maine Electric Co. automatic weigh larries (25-ton in inside aisles and 15-ton in end aisles); also a hand-operated auxiliary larry in each aisle.

ASH HANDLING

Type—Hydraulic sluicing system.
Installed by—Treadwell Engineering Co.
Capacity (ultimate)—30 tons per hour.

BOILER FEED

Sources and character of makeup—City water requiring no treatment (deaërated in condenser).
Feed pumps:
Size and type—8 in. 4-stage centrifugal.
Number per group of 8 boilers—3.
Make—Buffalo Steam Pump Co.
Capacity (each pump)—1,500 gal. per min.
Drive (pumps of 1 group)—1 pump direct-connected to 565 hp., 1,750-r.p.m., Terry Turbine; 2 pumps direct-connected to 625 hp., 1,800-r.p.m., 2,300-volt, 3-phase, 60-cycle, General Electric, variable-speed, slip-ring induction motors.
Feed-water regulation — Ruggles Klingemann Mfg. Co. (excess pressure), with Copes regulators).
Eductor condensers for high-pressure packing steam on turbine —Schutte-Koerting Co.

PRIME MOVERS

Make	General Electric Co.	Westinghouse Electric & Manufacturing Co.
Type	Curtis horizontal	Tandem compound reaction
Number (installed)	1	1
Rated capacity per unit	50,000 kw. (62,500 kva.)	
Space occupied	61½ ft. long, 22 ft. wide	80 ft. long, 22 ft. wide
Number of stages	21 (simple stages)	
Speed	1,200 r.p.m.	
Steam pressure and superheat at throttle	265 lb. gage and 200 deg. F.	
Type of generator	3-phase, 60 cycle, 13,800 volts, star connected	
Exciters	250 kw. direct-connected	225 kw. direct connected
Generator air-coolers to cool 120,000 cu. ft. per sec. from 152 deg. to 104 deg.	1 General Electric Co.	1 Griscom Russell Co.

HOUSE TURBINE

Type—Horizontal condensing.
Make—Westinghouse Electric & Mfg. Co.
Number (installed)—1.
Capacity—4,500 kw. at 75% power factor.
Speed—3,600 r.p.m.
Type of generator—3 phase 60-cycle 2,300 volt.
Type of service—Carries half auxiliary load of station.
Exhaust—Heats feed water ahead of bleeder heaters.

CONDENSERS (Same for both main units)

Type—Surface, radial-flow, two-pass.
Make—Westinghouse Electric & Mfg. Co.
Used with—50,000 kw. turbines.
Number (installed)—2.
Tube surface—70,000 sq.ft.
Sq.ft. of tube surface per rated kw. of prime-mover—1.40.
Tubes—1 in. o.d., 20 ft. long, admiralty mixture.
Number of tubes—13,368.
Tubes furnished by Baltimore Tube Co. and American Brass Co.
Over-all dimensions—Diameter, 22 ft. 7 in.; length, 30 ft. 8¾ in.

CIRCULATING PUMPS

Number and make—2 (Westinghouse) per condenser.
Drive—Direct-connected 600 hp., 2-speed, 60-cycle 3-phase 2,300-volt squirrel-cage motors.
Capacity—51,665 gal. per min. (each).
Capacity per kw. installed—2.07 gal. per min.
Circulating-water tunnels—Intake, 2, 11-ft. wide x 18 ft. 8 in.; Discharge, 1, 15 ft. wide x 18 ft. 8 in.
Hotwell pumps—900,000 lb. per hr. driven by 100-hp. Westinghouse motors.
Type of screens—Rex Revolving (Chain Belt Co.).
Number and size—4 (installed) 10 (ultimate); height, 30 ft.; width, 10 ft.

AIR PUMPS

Number per condenser, make and type—1 Westinghouse LeBlanc Air Pump for each condenser. As a spare, a bank of 2 Westinghouse 2-stage ejectors in parallel with surface-type intercoolers and after condensers.
Capacity—Cu.ft. per min. of dry air at 75 deg., 29 in. vacuum: LeBlanc, 22; ejector bank, 38.

HEAT BALANCE

General method for one group—Condensate (2 streams) from main unit passes through inter-coolers and after-condensers of respective air ejectors; then streams unite and pass through house-turbine condenser to feed pumps; then streams divide and pass through low- and high-pressure bleeded heaters of respective main units to boilers.
Bleeder heaters, number and make—4 per group, 2 per turbine, Wheeler Condenser & Engineering Co.
Type and details—"U"-tube 3,500 sq.ft., tubes ¾-in. o.d., 16 B.w.g. seamless copper; 4 passes; shell cast and rolled steel; tube sheet, 4-in. thick Muntz metal.
Connections—General Electric unit, 10th and 16th stages; Westinghouse unit, between cylinders and at start of l.p. double-flow section; both units, pressures at ¾ load about 55 lb. abs. and 10 lb. abs.; pair capable of heating 500,000 lb. per hr. from 113 deg. to 325 deg.

PIPING

Steam and boiler feed—12-in. and over, wrought steel ⅜ in. thick, Vanstone joints; under 12 in., E. H. wrought steel.
Fittings—1½-in. and over, E. H. cast steel (flanged); under 1½ in., E. H. forged steel screwed.
Piping furnished by Reading Steel Casting Co. and Ballwood Co.
Fittings furnished by Reading Steel Casting Co. and American Foundry & Construction Co.
Piping erected by Shevlin Engineering Co.
Condenser piping—Cast iron, Weatherly Foundry & Machine Co., Kutztown Foundry & Machine Co., Fuller Lehigh Co.
Atmospheric relief piping—Spiral-riveted pipe furnished by American Spiral Pipe Works.

PRINCIPAL VALVES (by makers)

Chapman Valve Mfg. Co.—Gate, motor-operated.
Consolidated Safety Valve Co.—Pop safety.
Edward Valve & Mfg. Co.—Misc. globe, stop and check, atmospheric relief.
Kieley & Mueller Co.—Float valves.
Lunkenheimer Co.—Miscellaneous globe.
Schiller Nolan & Co.—Blowoff.
Schutte-Koerting—Miscellaneous globe, float, chronometer, bleeder.
Wheeler Condenser & Eng. Co.—Ball-check float.
W. E. Williams Co.—Heater relief.

HEAT INSULATION (steam and hot water)

High-pressure superheated lines (to resist 700 deg.)—85 per cent magnesia protected with inner layer of J. M. high-temperature insulation and surfaced with ½ in. hard finish cement, total thickness ranging from 1½ in. to 4 in. for 10 in. and larger pipe.
High-pressure saturated lines—85 per cent magnesia ranging from 1½ in. to 2½ in. thick.
High-temperature boiler-feed lines—85 per cent magnesia 2 in. to 2½ in. thick.
Pipe covering supplied and applied by—Johns-Manville, Inc.

AIR COMPRESSORS

Number and type—2, two-stage, direct-connected, driven by 560-hp. General Electric 300-r.p.m. 107-hp. synchronous motors.
Make—Ingersoll-Rand Co.
Capacity (each)—560 cu.ft. free air per min.
Air pressure—100 lb. (gage).

MISCELLANEOUS PUMPS

Furnished by—Worthington Pump & Machinery Co.
Centrifugal pumps—1 fire, 1 salt-water house service, 3 oil cooling, 3 heater condensate, sump (Goulds Mfg. Co.), 1 eductor-condenser priming, 1 drinking water, 1 condenser-filling pump.

GAGES, METERS AND INSTRUMENTS

(Make, type and number.)

Bailey Meter Co.: Boiler meters (2 per boiler).
Bristol Co.: Steam pressure, vacuum, draft, automatic recorders operating on Warren-clock system—20.
Foxboro Co., Inc.: Draft gages—9.
Builders Iron Foundry: Venturi meters (charts operated by Warren clocks)—13.
Crosby Steam Gage and Valve Co.: Indicating pressure gages—49.
General Electric Co.: Flow meters—7.
Taylor Instrument Cos.: Thermometers.
Leeds & Northrup Co.: Temperature Recorders (driven by Warren clocks)—9.
Yarnall Waring Co.: V-notch blow-down meter—1, V-notch storage-tank overflow meter—1.

CRANES

Traveling cranes in the operating room—Morgan Engineering Co. First crane: Main hoist 150 tons, auxiliary hoist 15 tons. Second crane: Main hoist 150 tons, auxiliary trolley with 75-ton and 10-ton hooks. Both cranes: 95 ft. span, 80-ft. hook lift.
Ash-handling crane on wharf: Brown Hoisting Machinery Co., 5-yd. bucket.
Other cranes and hoists—Northern Engineering Works: One 10-ton hoist, two 5-ton hoists, one 25-ton crane; Whiting Corporation: One 35-ton crane.

MISCELLANEOUS EQUIPMENT

Ash-sampling device: Bergen Point Iron Works.
Subway grating: Irving Iron Works Co.
Miscellaneous tanks: Treadwell Construction Co., Franklin Machine & Boiler Works.
Warren clock system: Simplex Time Recorder Co.
Oil coolers: Schutte & Koerting Co.
Load indicators: General Electric Co.
Water meters and fish traps: Neptune Meter Co.
City-water lines (20 in.): R. D. Wood & Co.
Log and emergency screens: Turl Engineering Co.
One-ton ash-door hoists: A. Appleton Co.
Electric capstans (25,000 lb.): Lenher Engineering Co.
Cast-iron screen guides: Foran Foundry & Mfg. Co.
Control panels: Philip Lenges Iron Works.
Steam whistles: Charles Corey & Sons.

Finding the Cost of Exhaust as Compared to Live Steam

Why Exhaust Steam Should Be Cheaper Than Live Steam—Some Typical Examples

By C. E. COLBURN*

SINCE the low-pressure exhaust steam can be supplied at lower cost than the live steam, it should be charged to the different departments at this reduced cost in order to encourage its use rather than the more expensive live steam. It is thought that the confusion sometimes existing with regard to such charges is in most cases due to lack of understanding of why an equal amount of heat can be supplied cheaper in the form of exhaust than in the form of live steam. To assist in a clearer understanding of this as well as many other problems, we will consider an extreme example.

It is well known that even with efficient turbines, nearly seventy-five per cent of the heat in each pound of steam at the throttle is exhausted from a condensing unit and given up to the cooling water. This vast amount of heat is of no value to the power plant since it represents steam that cannot be further expanded to do useful work. If steam at this temperature could be used in some manufacturing process, it would be manifestly unfair to charge for it the same as is charged for live steam, because it is valueless to the power plant and would normally be wasted. Where exhaust steam is supplied for a manufacturing process at a pressure above the normal exhaust, a charge should be made because the steam furnished could have been expanded to a lower pressure so as to obtain more work from each pound provided the proper equipment were available.

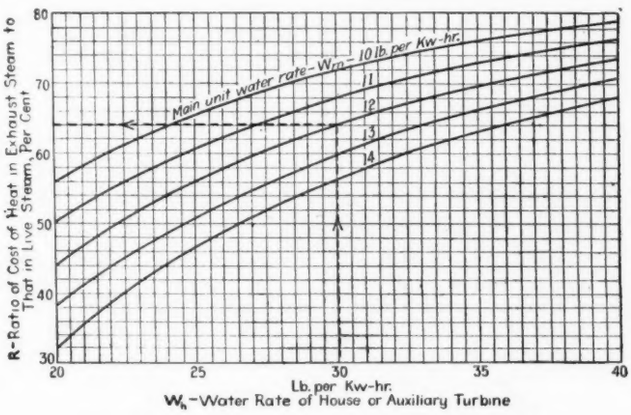
Comparing Air Ejector with Piston Pump

In a power plant it is frequently desirable to know the cost of steam exhausted from a house generator or auxiliary drive turbine. It is seldom if ever necessary to know the cost in dollars and cents, it being only required to have the cost in relation to the cost of live steam. At the Mount Hope plant (described in the Jan. 15 issue) the departments were charged 50 cents per thousand pounds for live steam and 35 cents per thousand pounds for exhaust steam. The figures show that at this plant exhaust steam cost 70 per cent as much as live.

As an example of how such a relative cost figure is of use in power plants, let us consider the problem of determining whether it is more efficient to use steam air ejectors or a motor-driven pump for air removal from a turbine condenser. The ejector exhaust is to be used in heating feed water. Suppose 60 kw. is required to operate the motor-driven pump and that a bank of ejectors large enough to accomplish the same amount of air removal would use 1,400 lb. of steam per hour.

With a station water rate of 13 lb. per kw.-hr. the steam required in the main condensing turbine to furnish the 60 kw. needed for driving the vacuum pump would be $60 \times 13 = 780$ lb. per hour. Since this steam is used in a condensing turbine, the heat in the exhaust is given up to the cooling water in the condenser and is lost. In the case of ejectors, however, the steam is exhausted, together with the air removed, at nearly atmospheric pressure, for use in heating feed water. Neglecting the radiation losses in the ejector and piping, the heat available for feed-water heating in the steam will be as great as in the original live steam.

Suppose the heat in the exhaust steam in the plant at present used for feed-water heating cost 60 per cent as much as live steam. A part of this would be replaced by the steam exhausted from the air ejector. It can be said that the live steam has been lowered 40 per cent in value by being passed through these ejectors. It replaces steam worth 60 per cent as much. The effect is just the same as if 40 per cent of the actual steam consumption were used, where no heat is available for feed-water heating.



Finding relative cost of exhaust steam from turbine water rates

Air Ejectors Are Not 100 per Cent Efficient Although Boiler Receives All Heat in Steam

Taking 40 per cent of 1,400 lb., the actual steam consumption, gives 560 lb. per hour, the equivalent live steam consumption. Since the equivalent steam consumption of the ejectors is lower than 780 lb. per hour, the steam required to furnish the power to operate the vacuum pump, it can be concluded that the air ejectors are more economical for the conditions assumed than a motor-driven pump.

It has often been stated that steam air ejectors are nearly 100 per cent efficient because there is practically no heat loss, owing to the fact that the heat in the

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exhaust is absorbed in the feed water. Although this is actually not a misstatement, it frequently is misleading to those who do not realize that the heat exhausted by these ejectors can be used only to replace steam that would otherwise have been obtained from the exhaust of a house turbine or bled from a main turbine. Consequently, it is worth only around 30 to 70 per cent as much as the heat supplied in the form of live steam to the ejectors.

In the case of power plants where the main turbines are run condensing and the feed water heated by steam exhausted from an auxiliary drive or house turbine, the relative cost of exhaust steam as compared to that of live steam denoted by R is given by the following equation:

$$R = \frac{(W_h - W_m)H_f - W_m(t_f - t_c)R}{W_h \times H_f - 3{,}412 \times C} \qquad (1)$$

in which

R = The ratio of the cost, or added B.t.u. per kw.-hr. of auxiliary turbine, to the gain in B.t.u.

W_h = Water rate of the house or auxiliary drive turbine in lb. per kw.-hr.;

W_m = The water rate of the main condensing turbines in lb. per kw.-hr.;

H_f = $(H_s - t_f + 32)$, when H_s is the heat content of the live steam;

C = A constant, which may be taken as 1.08 for a house turbine and 1.10 for small auxiliary turbines;

t_f = The feed-water temperature;

t_c = The condensate temperature.

The numerator of equation (1) expresses the cost or added amount of heat that must be supplied by the boilers to develop a kilowatt-hour in the house or auxiliary drive turbine.

The denominator shows the amount of heat that is available for feed-water heating per kilowatt-hour of work done by the auxiliary drive or house turbine. It represents the gain in B.t.u. per kilowatt-hour of auxiliary turbine. Thus, 1 B.t.u. exhausted represents $1 \times R$ in B.t.u. of live steam which is required extra to produce it, the electrical energy being absorbed by the station load.

Since the value R appears on both sides of the equation (1) it is made more convenient for use when converted into the following form:

$$R = \frac{H_f(W_h - W_m)}{H_f \times W_h - 3{,}412C + W_m(t_f - t_c)} \qquad (2)$$

The chart shows the value of R for various values of main unit and house or auxiliary drive turbine water rates for a feed-water temperature of 210 deg. F. and a condensate temperature of 80, with live steam having a heat content of 1,320 B.t.u. Since the heat content of the live steam and the condensate and feed-water temperatures only slightly affect the value of R, it will be sufficiently accurate in practically all cases to take the values shown in the chart rather than work through the equation. This value of the relative cost of exhaust steam should be determined for every plant because where the utmost in economy is sought, the figure will be frequently needed in solving operation problems.

The use of the figure is illustrated by the following example:

In a given plant the main unit water rate is 12 lb. per kw. average, operating with 210-deg. feed water and a condensate temperature of 80. Steam for heating was obtained from a non-condensing house turbine whose average water rate was 30 lb. per kw. and which with the main unit was supplied with steam at 300 lb. gage and 200 deg. F. superheat, of heat content about 1,320 B.t.u. per lb. It was desired to know what the exhaust steam heating was costing as compared with live steam, for purposes of calculation. Steam withdrawn for heating here represents the denominator of the fraction.

In this case, W_m is 12; W_h, 30; t_f, 210; t_c, 80; H_s, 1,320, and C, 1.08. Then, by substituting

$H_f = 1{,}320 - 210 + 32 = 1{,}142$ B.t.u.

and

$$R = \frac{1{,}142(30 - 12)}{(1{,}142 \times 30) - (3{,}412 \times 1.08) + 12(210 - 80)}$$

$R = 0.64$

This means that the heat in the form of steam exhausted from the house turbine was worth 64 per cent of the cost of an equivalent amount of heat supplied in live steam, representing a 36 per cent saving over the same heat from live steam.

Lines have been dotted in to show the solution of the foregoing problem graphically. By beginning with W_h equal to 30 and going vertically upward to W_m, equal to 12, then horizontally, the value of R is found to be 64 per cent.

Cost of Steam from Several Turbines

In the case of a small plant having several auxiliary drive turbines, in order to obtain the combined water rate, the process of averaging, known as weighting, must be followed out. If we have four small turbines whose water rates, W_{m_1}, W_{m_2}, W_{m_3} and W_{m_4}, are 42, 25, 32 and 28 lb. per hp.-hr. and whose loads or rated horsepowers, if the actual loads are not measurable, H_1, H_2, H_3 and H_4, were 90, 300, 96 and 150, to find the average turbine water rate of this group substitutions are made in the following formula as shown:

Weighted average water rate =

$$\frac{(W_{m_1} \times H_1) + (W_{m_2} \times H_2) + (W_{m_3} \times H_3) + (W_{m_4} \times H_4)}{H_1 + H_2 + H_3 + H_4}$$

Substituting, the average water rate is,

$$W_{.R.} = \frac{(42 \times 90) + (25 \times 300) + (32 \times 96) + (23 \times 150)}{90 + 300 + 96 + 150}$$

Solving, $W_{.R.}$ is found to be 29.2 lb. per horsepower.

In order to reduce this to an equivalent value per kilowatt, it is necessary to divide by 0.746, which will give a water rate based upon 1 kw.-hr. of 39.2 lb. Substituting values of the factors as in the previous problem, remembering that the value 1.10 should now be used for C, we get the value of R equal to 73 per cent.

By assuming a series of values of W_m and W_h, it is possible to plot curves for any plant as required, the other factors in the equation remaining constant through any one set of curves. Care should be taken always to convert W_h and W_m to the same base, such as pounds per kilowatt-hour or pounds per horsepower-hour in calculating results.

Where exhaust for heating feed water is supplied by one turbine and it is desired to figure the cost of steam exhausted from another, this equation is true only when both the water rates are equal. Otherwise, calculate R for the house turbine heating feed water, from equation (2). Use it at the right in equation (1) when computing R for the second turbine furnishing steam for other purposes. Equation (2) does not apply for the second turbine.

Control of Auxiliary-Drive Motors

Automatic Regulation of Motor Speed—Control of Stoker Drives —Use of Two Motors for Driving Forced- and Induced-Draft Fans —Automatic Change Over from One Source of Power to Another

BY A. L. HARVEY
Control Engineer, Westinghouse Electric & Manufacturing Company

ALL the drives for the power-station auxiliaries are such that electric motors may be used if other conditions do not make steam drive preferable. It is, however, necessary to have some units steam driven to provide for starting up the station, unless the plant is tied in with other generating stations on a large system.

The source of electric power for the auxiliaries should be in duplicate or with a means of transfer to some other source of power for emergency operation. In a few stations direct-current motors have been used for the auxiliaries, in which case a storage battery can be employed to obtain emergency auxiliary power. This provides a reliable reserve, but it is usually at a relatively higher cost than when alternating-current is used. For some of the adjustable-speed drives, especially stokers, where the torque requirements are variable at any given speed, a source of direct current is necessary or desirable. If the total amount of power for stokers is small, this can be provided by two motor-generator sets.

Some stations use automatic regulation on those units where it improves the operation of the plant. In some cases stokers are controlled in accordance with the load demand, but as a general rule this is not usually considered necessary, and the automatic regulation of stokers may not be desirable in some cases.

A medium speed can be maintained on the stoker feed, which will permit wide fluctuation in load for short periods without noticeably affecting the combustion conditions. The stoker carries a very considerable reserve of heat in the form of ignited coal and coke on the grates. This reserve is used when the air pressure is increased under the fire as is the case when the load increases on the boiler, and the reserve is again built up when the load decreases on the boiler with a consequent reduction in the draft. Except for the wide variations, lasting for periods of probably ½ hr. or longer, the stoker drive requires little attention.

Even when automatic regulation is used on the stoker equipment, the variation in combustion efficiency and in the quality of the coal will make it necessary to adjust the stoker speed nearly as much as when automatic regulation is not used.

The efficiency of the plant is largely determined by the combustion conditions, and many plants use automatic regulation on the boiler-draft fans to obtain quicker response to the various changes in load conditions. In some cases the forced- and induced-draft fans on a boiler or bank of boilers were controlled from one regulator. In other cases the forced-draft fan and the stoker are controlled from one regulator, but as previously stated, the rate of coal feed requires considerable adjustment and provision must be made to permit this to be done whenever necessary. Regulators may be used

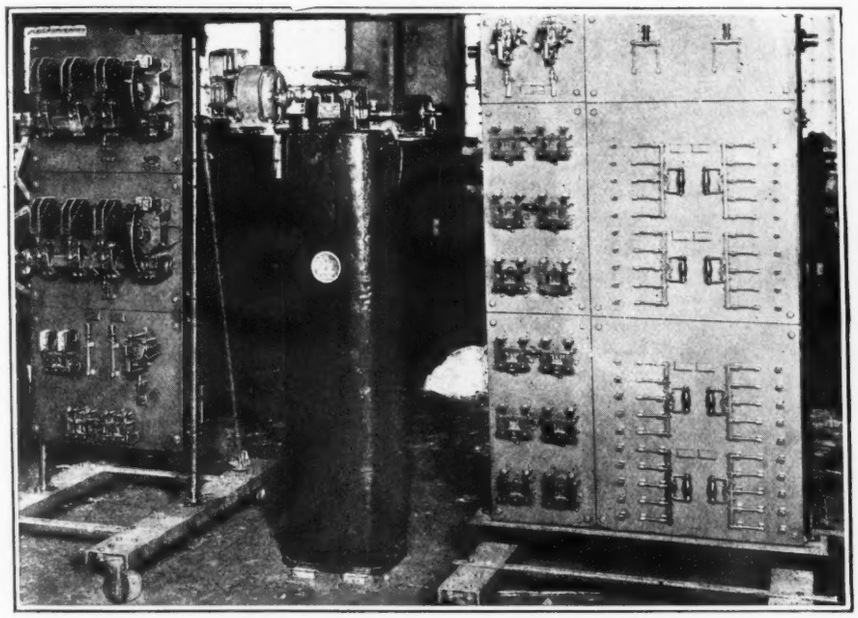


Fig. 1—Motor-operated control equipment for two-motor fan drive and master panel for eight equipments

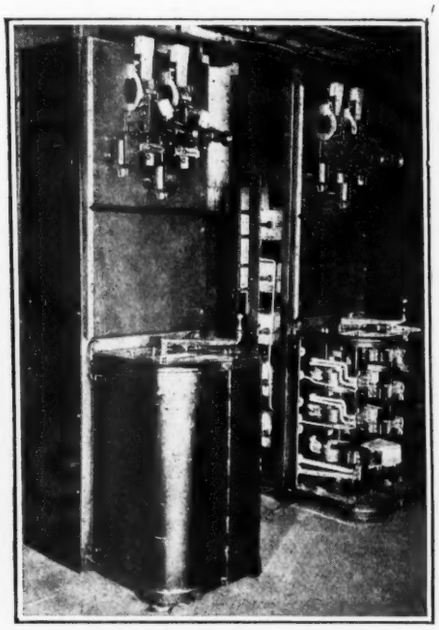


Fig. 2—Direct-current hand-operated controllers for fan drives

to adjust the dampers instead of motor speed, but slightly lower efficiency results when this is done.

The controllers used with automatic regulators may consist of a drum or faceplate operated directly by the regulator. In other cases it may be a motor-operated controller either mechanically or electrically connected to the regulator through a master drum, which makes the necessary connections for the operation of a pilot motor. When electrical operation is employed, it is necessary that some device be used to prevent the controller traveling beyond the point corresponding to the setting of the regulator.

Forced- and Induced-Draft Fan Drives

Practically all large stations use forced-draft fans to provide sufficient air for combustion, and those stations having low stacks and using economizers also use induced-draft fans. The load on the motor driving the fans varies approximately as the cube of the speed, and this fact makes the arrangement of a two-motor drive economical. Such an arrangement has been used in several stations. The ratio of the speeds is approximately 1 to $\frac{3}{4}$, so that the small motor is approximately one-third the horsepower rating of the large motor.

The control equipment is so arranged that the smaller motor starts the fan and drives it up to its rated speed. For higher speeds the controller automatically connects the large motor to the line and disconnects the small motor. Each motor has its own secondary resistors and contacts in the controller. Control for this type of drive is shown in Fig. 1. The equipment consists of a primary panel, on the left, and a motor-operated drum controller, in the center, electrically connected to a regulator by means of indicator motors, for each pair of motors; also a master control panel for all fans, shown on the right. The control circuits are arranged so that the fans may be operated (1) by the regulator, (2) in groups by a group push-button station or (3) individually by a push-button station. In emergency the drum controllers may be operated by the handwheel at the top of the drum. As the pilot motors are connected to the controllers through a worm-gear reduction, provision is made for disconnecting the gearing, and the hand operation is direct on the controller shaft.

The indicator motors are electrically the equivalent of a wound rotor motor with a single-phase stator connected to a supply circuit and a polyphase rotor connected in parallel with the other rotors. The transmitter motor is operated by the regulator, and each receiver motor on the controller follows the movement of the transmitter due to the shifting field.

The operation of the fans is essential to the full-capacity operation of the plant, and the control, as well as the motors, must be such as to withstand the service requirements. The induced-draft fans and motors are frequently mounted above the boilers where the ambient temperature is high, and the design must be such that satisfactory operation can be obtained under these conditions. The forced-draft fans, however, are usually mounted in a much cooler place and where it is comparatively clean.

Direct-current motors and control equipment have sometimes been used for fan drive. The Detroit Edison Co. has used direct current on practically all auxiliaries in one or two plants. Control of this type is shown in Fig. 2. The equipment consists of a panel mounted on an angle-iron frame to take a two-pole circuit breaker, drum controller and resistor. The circuit breaker is provided with a lockout device so that the controller must be in the "off" position before the circuit breaker can be closed. A shunt trip is also provided so that the breaker may be opened, to shut down the motor quickly in case of necessity. For the forced-draft fans the speed control is obtained with a separate drum-type field rheostat, while on some other auxiliaries the field drum is combined with the main drum.

The Brooklyn Edison Co. has used variable-voltage control, having a separate generator for a group of auxiliaries. The generator voltage is reduced for the slow-speed operation during times of light load, and resistance is inserted in the motor fields for high-speed operation, for full-load conditions. Motor-operated field rheostats are used with provision for adjusting the speed of each individual unit to the proper point with respect to the other units in the same group of auxiliaries.

As practically all stations except some industrial stations generate alternating current, it is desirable that this source of power should be used for the auxiliaries. This is the case for the constant-speed auxiliaries as squirrel-cage motors may be used, which is a reliable and simple type of motor with a low maintenance cost. The voltage on the larger motors can be relatively high so that the cost of installation of cables can be kept to a minimum. In emergencies power can be obtained from the main bus. Control equipment is usually simpler and less expensive as compared to that for other motors. Alternating-current equipment, however, is at a disadvantage when adjustable speed is required, as the efficiency is reduced owing to the losses in the resistor; and for applications where the torque is variable at different times, such as on stoker drive, considerably more attention on the part of the operator is required.

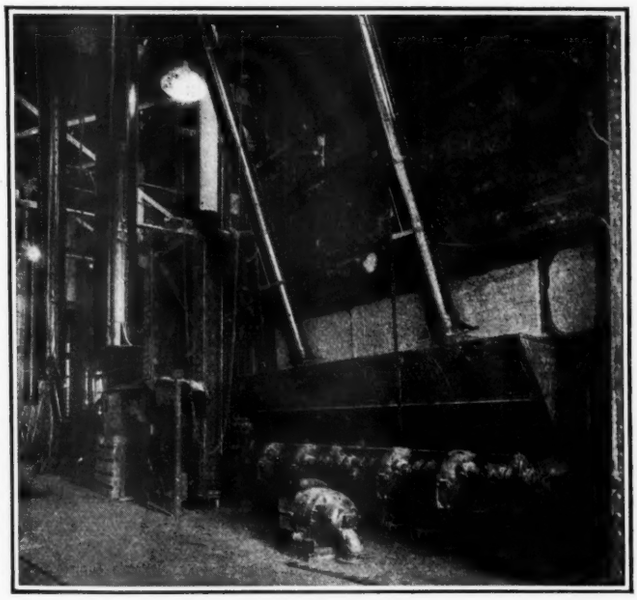
Advantages of Direct-Current Motors

Direct-current motors and control have the advantage of stability with adjustable speed under varying torque conditions. Emergency power can be obtained from a storage battery if available. This battery, however, has to be much larger than the station battery required for control circuit and emergency lighting uses. The direct-current equipment has the disadvantage of being more expensive and requires a greater investment in the power-converting equipment, as well as having higher maintenance charges. The low voltage required for successful commutation, under adjustable speeds especially, requires that the feeders be larger than those for alternating-current motors.

To supply power for emergency operation without a momentary shutdown of auxiliaries, it is necessary that some automatic changeover device be used to connect the motors from their usual source to the main bus or to some other emergency source of power. Such an equipment may be more or less complicated, depending on the total number of automatic features desired. Equipments for wound-rotor and squirrel-cage motors and transformers are installed in the Colfax station of the Duquesne Light Co. On a power failure a relay closes its contacts and energizes the trip coil of the circuit breaker that is closed. This operation completes other control circuits that allows the control relay for the other circuit breaker to close, again applying power to the motor with an interruption of a time duration required only to operate the apparatus.

Construction of Boiler Settings in Devon Station*

FURNACE walls for 16,800-sq.ft. boilers constructed entirely of firebrick. Arches are built in the walls to relieve the loading on the brick. Expansion joints filled with asbestos fiber divide the walls into vertical sections and allow for horizontal expansion. Vertical expansion is taken care of by expansion joints under the relieving arches and at the lower tube line. No heat-insulating bricks are used below the lower tube line.



WITH the high boiler settings now being used in modern power stations difficulties have been encountered in maintaining these settings in condition at a reasonable cost. This change in condition is due, first, to the nature of the settings themselves. They are much higher and the bricks have to sustain a larger compression load than in the lower settings, therefore more care has had to be given to their design. The second reason for the increased maintenance is that with these high furnaces more complete combustion of volatiles take place within the furnace, before the gases are cooled by contact with the heating surface of the boiler proper. This more complete combustion produces a higher furnace temperature, which has caused trouble with the brick settings. The third cause has been that with the high settings higher rates of combustion have been obtained with corresponding higher furnace temperatures.

In some of the modern plants experiments are being made on two methods of cutting down the original cost of boiler settings and at the same time obtaining longer life. These are by cooling the side walls by passing the combustion air through them and by protecting the refractories by heat-absorbing surface. The latter procedure is still in the experimental stage, but seems to be the more promising development. At the Devon station the designers endeavored to obtain satisfactory service by using a setting laid up almost entirely of firebrick, as indicated in the cross-sections, Fig. 2 on the following page.

Contributing causes to troubles with boiler furnaces are: First, the brick expands in the furnace face of the wall, and in that way causes the walls to bulge into the furnace. The lining of the wall then breaks away from its binding, and eventually portions of it fall in. A second difficulty which has occurred, has been that some boiler settings have been heavily insulated on the outside without sufficient provision being made for the bricks to radiate their heat. This has greatly increased the temperature of the refractories themselves and brought them up to their softening point. After the refractories have reached the softening point and they come in contact with the fine particles of ash leaving the fuel bed, this ash penetrates into the brick, spoils the refractory and the brick is eroded away. A third difficulty has been that the walls have been too rigidly constructed, so that with alternate heating and cooling, expansion has not been properly taken care of, and upon cooling, cracks have occurred.

In the Devon settings the side and rear walls have been made concave, so that as the face of the wall expands, it can only come out, approximating a straight line instead of becoming convex and bulging into the furnace. The side walls have also been tilted out at an angle of five degrees from the vertical. This serves to keep portions of the wall from falling into the furnace. These inclined walls are supported by steelwork on the outside (see Figs. 3 and 4), which helps to relieve the loading on the bricks in the hot zone. In all four walls relieving arches have been installed to take the load of the upper portion of the walls. This relieves the loading on the brick in the hot zone and also permits of ease in repairs. Each side wall is divided into three panels above and below the relieving arches by $\frac{1}{4}$-in. vertical expansion joints. The expansion joints, in passing through the walls, have a $6\frac{3}{4}$-in. offset and are packed with asbestos fiber. Under the

*Station at Devon, Conn., built by the Connecticut Light & Power Co. Described in the issue of *Power* for March 25.

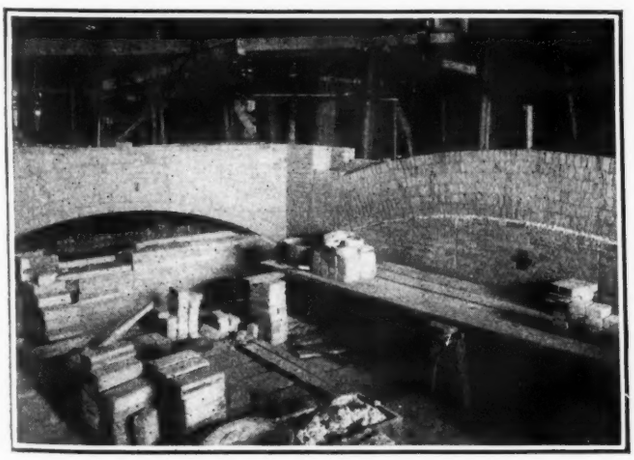


Fig. 1—Furnace walls under construction

relieving arches there is a 1¼-in. expansion joint, packed with asbestos fiber.

Difficulties have been encountered in some settings with the protecting wall, which is built up in front of the mud drum in this type of boiler (see Section *B-B*. Fig. 2). Soot leaks down between this wall and the mud drum when the boiler cools off, and upon the boiler heating up again, expansion takes place, and finally this wall is broken off and drops into the furnace. In order to overcome this difficulty, the front wall was carried up to within a few inches of the bottom of the mud drum. On the nipples connecting the mud drum with the headers, clips have been placed, upon which have been hung special tiles. These tiles then breathe with the boiler and serve to protect the mud drum. Asbestos is packed around the mud drum as indicated in the figure, but not between the top of the wall and the bottom of the protecting tiles. A metal cover has been placed around the outside, which, with the asbestos filling, prevents air filtration at this point. The con-

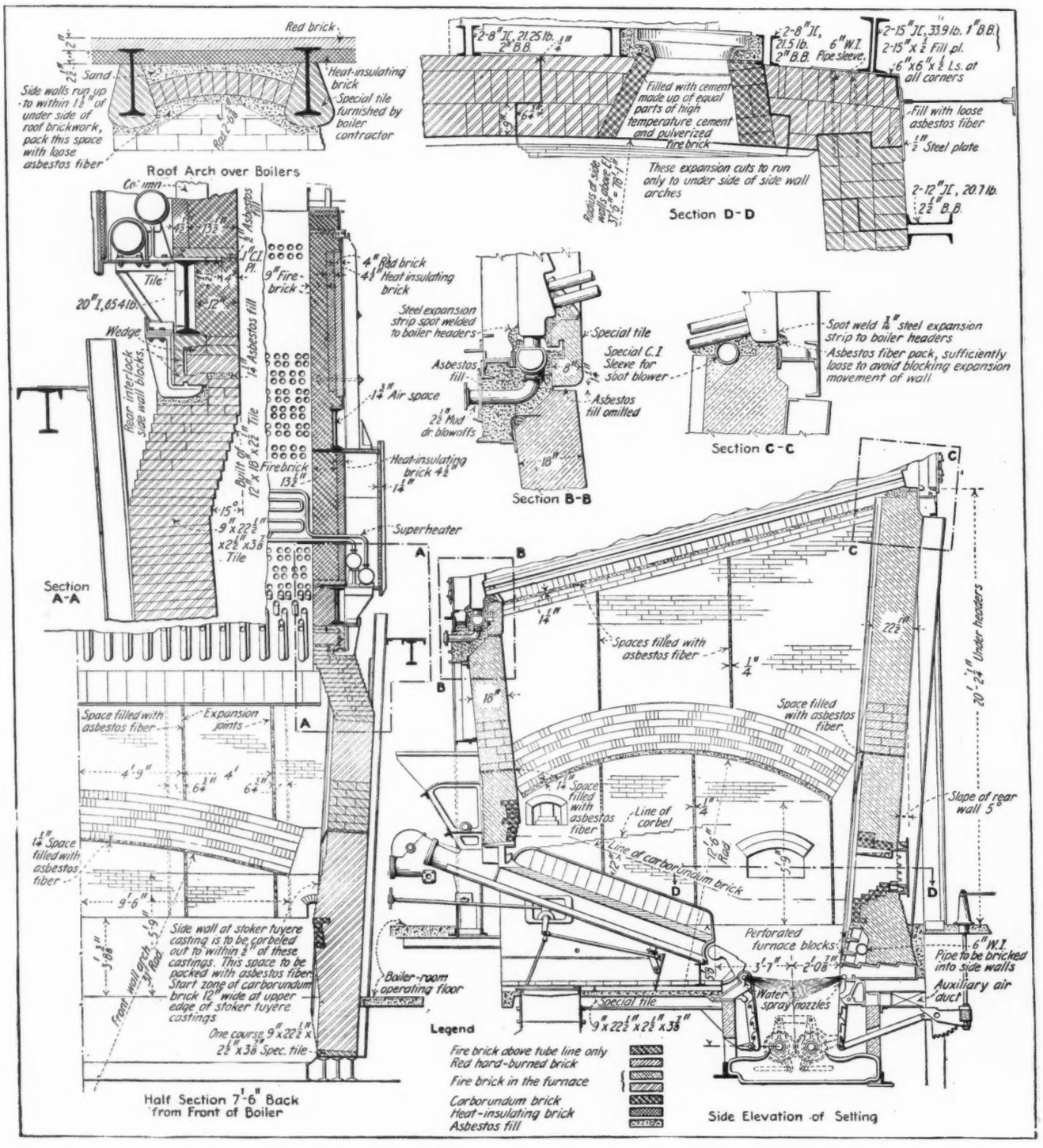
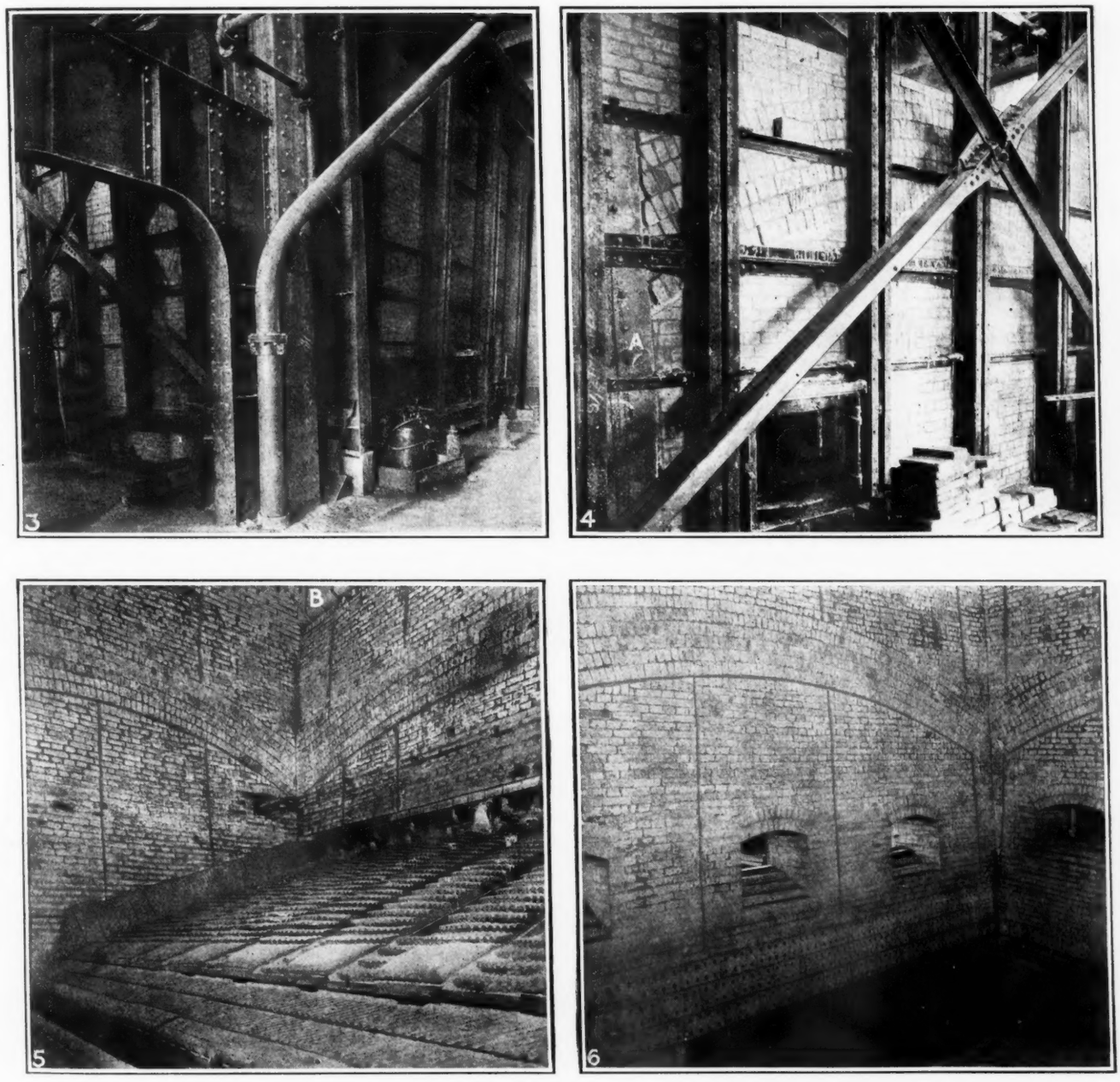

Red brick
Sand
Heat-insulating brick
Special tile furnished by boiler contractor
Side walls run up to within 1½" of under side of roof brickwork, pack this space with loose asbestos fiber
Roof Arch over Boilers
Column
Tile
20" I, 65.4 lb.
Wedge
Rear interlock side wall blocks
Asbestos fill
Built of 12" x 18" x 22½" Tile
Firebrick 13½"
15°
9" x 22½" x 22½" x 3⅜" Tile
Superheater
Section A-A
Space filled with asbestos fiber
Expansion joints
4'-9"
6¼"
4'
6¼"
1¼" Space filled with asbestos fiber
9'-6"
Side wall at stoker tuyere casting is to be corbeled out to within ½" of these castings. This space to be packed with asbestos fiber. Start zone of carborundum brick 12" wide at upper edge of stoker tuyere castings
One course 9" x 22½" x 2½" x 3⅜" Spec. tile
Front wall arch
3'-9⅜"
5'-9"
Half Section 7'-6" Back from Front of Boiler
4" Red brick
4½" Heat insulating brick
Steel expansion strip spot welded to boiler headers
Special tile
Special C.I. Sleeve for soot blower
Asbestos fill
9"
1¼" Air space
2½" Mud dr. blowoffs
Asbestos fill omitted
18"
Section B-B
Heat-insulating brick 4½"
1¼"
Section C-C
Spot weld ⅛" steel expansion strip to boiler headers
Asbestos fiber pack, sufficiently loose to avoid blocking expansion movement of wall
2-8" I, 21.25 lb. 2" B.B.
¼"
2-8" I, 21.5 lb. 2" B.B.
6" W.I. Pipe sleeve
2-15" I, 33.9 lb. 1" B.B.
2-15" x ½" Fill pl.
6" x 6" x ½" L.s. at all corners
Filled with cement made up of equal parts of high temperature cement and pulverized fire brick
6¼"
Fill with loose asbestos fiber
½" Steel plate
These expansion cuts to run only to under side of side wall arches
Radius of side walls above F.D. 37'-6" = 78½"
Section D-D
2-12" I, 20.7 lb. 2½" B.B.
Spaces filled with asbestos fiber
1¼"
18"
Space filled with asbestos fiber
1¼" Space filled with asbestos fiber
Line of corbel
Line of carborundum brick
2'-6" Rad
5'-9"
Slope of rear wall 5°
20'-2¼" Under headers
22½"
Perforated furnace blocks
3'-7"
2'-0⅞"
6" W.I. Pipe to be bricked into side walls
Auxiliary air duct
Water spray nozzles
Special tile
9" x 22½" x 2½" x 3⅜"
Boiler-room operating floor
Legend
Fire brick above tube line only
Red hard-burned brick
Fire brick in the furnace
Carborundum brick
Heat-insulating brick
Asbestos fill
Side Elevation of Setting

Fig. 2—Sections through boiler settings

struction of the expansion joint between the top of the rear wall and boiler header is shown in Section *C-C*, Fig. 2.

The most serious difficulty that had to be overcome in designing this boiler setting, was in tying the concave inclined walls into the vertical straight-line wall above the tube line. The brick was corbeled in and the portion of the side walls above the relieving arches. The walls below the tube lines are entirely of firebrick, in order to obtain a rapid heat transfer from them and to prevent the refractories from becoming overheated.

The ventilation of the boiler room is laid out so that the forced-draft fans draw their air down through the boiler room, so that radiation into the boiler room



Figs. 3 to 6—Views of the outside and inside of the furnaces

One of the steel plates for supporting the corners of the furnace asbestos-filled vertical expansion joints also those under the arches can be seen at *A*, Fig. 4. The special tile for protecting the mud can be clearly seen in Figs. 5 and 6. These expansion joints are drum of the boiler is seen at *B*, Fig. 5. The location of the ¾-in. and 1¼-in. wide respectively.

tied to a special side-wall tile construction in order to make this seal (see Section *A-A*, Fig. 2). The tiles are supported on hangers attached to a 20-in. I-beam that takes the weight of the upper wall. At this point there is a 1¼-in. asbestos-packed expansion joint. This relieves the top of the furnace walls of any loading and at the same time allows for the vertical movement of

from the furnace walls is not lost, but is utilized in the combustion air. This also serves to make the boiler room livable during both cold and warm weather, as by the adjustment of the windows in the fan floor and the monitors overhead, the quantities of air drawn from the boiler room by the forced-draft fans can be varied to meet the requirements.

Prime Movers for Industrial Plants

A comparison of the various types of engines and turbines for use in industrial plants, with a summary on economies and relative advantages.

By JOHN F. FERGUSON*

IN THE last few years there has been considerable advancement in prime movers for central stations, but not so much attention has been paid to the prime mover for industrial service. At best, little has been accomplished, not because of the lack of opportunities, but rather because of the failure of engineers to see these opportunities or to give them the attention industry deserves. At present and for some time to come the field offering the greatest possibilities for saving in power generation and fuel conservation lies in the industrial power plant. In the development of large steam central stations the peak in the efficiency curve is already in sight.

Some of the items having a direct bearing on the selection of a prime mover are: Initial steam pressure and temperature and back pressure; the space available and the dimensions of the unit; the first cost of the unit completely installed; the mechanical and thermal efficiency of the unit over the load range common to the plant; the manufacturer's time of delivery; the quality of workmanship in the machine; the reputation, reliability and standing of the manufacturer. In new installations the working conditions, workmanship and cost are the main items.

Single-Valve Engines

Single-valve engines have been produced in a greater variety of types and applied to more classes of service than any other type of steam engine, beginning with the old throttling-valve mill-type engine with D slide valve, followed by the double ported balanced valve and finally by the piston valve. The valve last named has a broader field and wider application than the others. It is used in locomotives, marine engines, stationary engines of the inclosed type, and in practically all classes of auxiliary engines. In stationary engines the English manufacturers have adhered largely to the piston valve, which so far has withstood any operating pressures and temperatures that it has been called upon to meet. Its advantages are: Reliability; simplicity in design, manufacture and repair; low maintenance costs; large port opening obtainable; minimum or no lubrication required. In view of these advantages it is likely that the piston-type valve will remain with us for some time.

Four-Valve Engines

Four-valve engines are found in all classes of industrial plants and in some of the older and smaller central stations, poppet, gridiron, piston, Corliss or other types of valves being employed. The Corliss valves of the releasing type, as used on the larger and slower-speed units, and the non-releasing or positive motion of the smaller or high-speed engines have given good service, but are not as well-suited to new high-pressure installations. This applies also to any other valve having a sliding contact with the seat unless of a balanced type.

As steam pressures and temperatures increase, internal lubrication of engines presents greater difficulties, hence the adoption of a valve to reduce such troubles to a minimum. The poppet valve perhaps approaches the requirements as near as anything yet produced, because there is no sliding contact or wearing surface except the valve stem, and this is reduced to a minimum on account of the large valve opening that can be gained with a slight movement of the valve and stem. Some types of balanced piston valves are giving excellent results under extreme conditions.

Many operators have questioned the possibility of the steam engine to keep in line with the increasing pressures and temperatures, but any doubt along this line is due to lack of foresight and confidence in the reciprocating unit. It is safe to predict that before long reciprocating units will be operating at pressures and temperatures much beyond what has yet been attempted.

Unaflow Engines

The unaflow principle has certain advantages in engines operating condensing or against low back pressure. Under these conditions the steam rate follows almost a straight line and is uniform over a wide range in load. This is desirable for engines working under a varying load, but this advantage decreases as the back pressure increases accompanied by approach to full-load rating. Primarily, this type of engine was designed for condensing service, and here its advantages are most pronounced, permitting a wide range of expansion that can be cared for economically in a single cylinder.

When the unaflow engine was applied to industrial work, imposing back-pressure operation, so that the exhaust steam might be used for heating, drying and process work, it was found that the exhaust port at the end of the stroke could not satisfactorily permit of proper expansion of the steam, take care of the exhaust, and keep the compression within the limits of the initial pressure, without excessive clearances and large cylinder volume. It became necessary, therefore, to make use of relief or auxiliary valves at or near the admission end of the working cylinder to allow a part or all of the exhaust steam to pass and thus keep down compression and reduce cylinder clearance and volume.

In studying the different load conditions and back pressures, with the relief or auxiliary exhaust valve adjusted for the best results for each condition, it will be found that the amount of exhaust steam passing out of the central port will vary from 100 per cent when exhausting into a good vacuum to a comparatively small amount when working against a back pressure and expanding down to the release pressure or less. With a working back pressure of from 17 to 25 lb. absolute, common in industrial service, the amount of steam passing through the central exhaust port of the unaflow engine, at its most economical working load, ranges from 10 to 20 per cent, reducing the gain possible under more favorable working conditions.

As the percentage of the exhaust steam passing through the central port decreases from 100 per cent,

*Ferguson Engineers, Chicago, Ill.

the advantages gained by the unaflow principles begin to decrease.

The question may arise, "Why not compound unaflow engines?" In this case the high-pressure cylinder is working against an extreme back pressure from which little advantage can be expected, so that much of the gain in economy due to unaflow principles would have to be obtained from the low-pressure cylinder. Then to consider an engine with a four-valve counterflow high-pressure cylinder and a unaflow low-pressure cylinder would depend upon whether the total expansion from initial pressure to exhaust was of sufficient range to warrant more than one cylinder; also upon the average load conditions and the back pressure against which the low-pressure cylinder would work. For condensing and low-back-pressure work the latter combination would be desirable and efficient, but when working under the usual loads and back pressures common to industrial plants, the gain in efficiency over the single-cylinder unaflow engine would be small.

Steam Turbines

In central stations the steam turbine has replaced almost universally the reciprocating engine. It has gained ground also in the private plant of the industrial field, in the writer's opinion more than has been warranted, because they have been installed in many places regardless of their adaptability to the service. Such installations are due to a lack of knowledge of their advantages and disadvantages and the class of service to which the different types of turbine are best adapted.

While it is possible to secure fairly low steam rates in small turbines, the cost of such units in the small sizes is high, so that in many cases the manufacturers have favored sacrificing economy for lower first cost. In steam units of the sizes such as employed by large public-utility stations, the competition between the steam turbine and the engine does not exist.

Comparing the impulse and reaction types of steam turbine, the commercial impulse machine possesses an advantage in that it may be controlled or governed by the opening and closing of additional steam nozzles or groups of nozzles, thereby taking advantage of the full expansion of the steam as far as possible. In the reaction turbine the initial pressure is reduced generally by throttling, so that the turbine is actually working on reduced initial pressures at light loads. This affects the steam rate, increasing it faster as the load is reduced than with the individual nozzle control. The loss is greater as the working back pressure is increased, narrowing the range between the initial and the exhaust pressures. Of course all impulse turbines do not have nozzle or nozzle-group control; many are throttle-governed and do not possess the foregoing advantages. The impulse design generally permits of greater radial clearance for the turbine rotor and is ordinarily less affected by slugs of water that may come over with the steam; also it is less liable to become clogged up with scale or dirt carried over with the steam. This last item is of minor importance as no up-to-date plant will permit such steam conditions to exist.

For the two types of turbine at full load the steam rates are practically equal, except that it is considered by some turbine experts that the impulse type has the advantage in the earlier part of the expansion, due partly to the governing effect at light loads and the reaction in the latter part of the expansion.

Practically all small steam turbines used for driving auxiliary units, such as pumps, fans, etc., are of the impulse type with a single wheel and one or two or perhaps three rows of buckets and a throttling governor.

As a prime mover the advantages of the steam turbine are: Minimum space required both in floor area and in height; lighter weight, permitting of smaller, lighter and cheaper foundations; minimum adjustment in the machine, permiting long and continuous service; no internal lubrication and elimination of oil in exhaust steam or condensate. The disadvantages of many of the small steam turbines are high steam rates and high speeds for direct connection to direct-current generators and certain types of drive and equipment. The high steam consumption of the small non-condensing turbine economically limits its use to certain industries where the ratio of power demand to steam demand for manufacturing is comparatively low or where there is no available use or market for any excess power that may be abstracted from the steam.

Bleeder Extraction Turbines

Bleeder extraction turbines were designed to meet the demand for a combination back-presure and condensing machine that would permit the bleeding of steam at a predetermined pressure for manufacturing processes, heating, etc., up to certain limits, and maintain a balanced condition throughout any variation or interruption in either the power demand or in the steam drawn from the bleeder section of the machine. While the principle is ideal, the machines sometimes have not lived up to their possibilities, owing to their not being correctly proportioned to the service demanded.

Turbine manufacturers have been inclined to give the low-presure or condensing section of the turbine more attention than the high-pressure element, whereas in most cases it should be the reverse. As the steam bled is fixed by the mill demand, the turbine should be proportioned so that the amount of steam to the condenser will be as small as is possible, and in many cases zero if the high-pressure section is of the highest efficiency. If this point is overlooked, a turbine of the bleeder-extraction type may easily prove to be an extravagant machine. Before installing a turbine of this type, a careful study should be made of the operating conditions, as in some cases it is quite possible that a straight non-condensing or back-pressure turbine of economical design will prove more satisfactory and efficient, besides reducing the investment.

To design a bleeder turbine for highly economical results, the special requirements of the specific plant should be considered. The difficulty has been that the characteristics desired of a bleeder turbine in the different industries, or even in the same industry, vary to such an extent as almost to prohibit the use of a standard machine. The requirements in one case may be just the reverse of what is demanded in another, so that for best results the bleeder turbine should be specially designed for any particular installation.

Comparative Economies

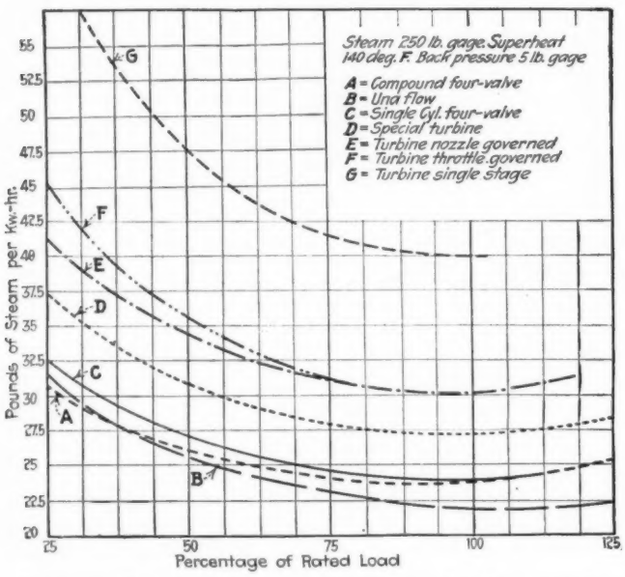
In the accompanying curves are given average rates of several different types of prime mover for industrial power plants based on a moderate steam pressure of 250 lb. gage, 140 deg. superheat and 5 lb. working back pressure for sizes of 750 to 1,500 kw. No attempt has been made here to present steam rates of condensing units.

Curves *A*, *B* and *C* show the higher economies of

reciprocating units. Curve *D* indicates what can be accomplished with a turbine of the higher class and of special design. Curves *E* and *F* give steam rates for the best class of steam turbines and show the advantages and disadvantages of throttle-governed units. Curve *G* represents the economy of small single-stage steam turbines commonly found in industrial plants.

When rebuilding power plants, too often prime movers are selected with only the existing steam and factory conditions in mind, instead of selecting units that can be converted to a great extent to advanced conditions at any time with minimum changes.

In most industries there is a demand for steam in manufacturing, heating and drying that permits abstracting all or a great part of the power required to



Comparative steam rates for non-condensing service

operate the entire factory, so that the demand for condensing units in industry should be small.

With a careful study of present tendencies and possibilities and looking into the future for lower power costs and greater efficiencies, the situation with regard to prime movers for the industrial plant may be summed up as follows:

The single-valve engine of the piston type will continue to survive for driving auxiliary equipment and as a multiple-expansion engine of marine and English stationary types, locomotives, etc., where simplicity and reliability are of prime importance.

The Corliss type and other unbalanced four-valve engines will, in the writer's opinion, give way to the four-valve engine of the poppet type, designed for operation under extra high pressures and temperatures with the minimum or no internal lubrication. Such engines should be compound or multiple-expansion not only for higher mechanical and thermal efficiencies, but for better mechanical-engineering principles in engine design, higher piston speeds, reduced weight, lower first cost and less floor space per unit of capacity.

The unaflow engine will continue to survive as a single-cylinder engine for light and varying load conditions working against low back pressures, but is limited to low or moderate initial steam pressures and temperatures. A new use for this machine as the low-pressure element of compound and multiple-expansion units exhausting to a vacuum or low back pressure may prove eventually to be its greatest field.

The single-stage, cheaper and extravagant types of steam turbine for driving plant auxiliaries will give way to motor drive except in some cases as reserve units.

The high-pressure condensing steam turbine will (except in industries where there is no demand for steam in the manufacturing plant) give way to non-condensing or back-pressure units of economical design delivering steam for manufacturing uses. In such industries, where the power demand is great and the uses for steam in manufacturing are small in proportion, a combination of high-pressure and low-pressure units should prove most economical.

There will be a field for the bleeder or extraction steam turbine where the power demand is greater than the steam demand for manufacturing, but the service calls for a high-class, efficient turbine carefully designed in accordance with the specific conditions of the plant.

The reciprocating steam engine will retain its place as a prime mover in industry. In fact, at the present time there are several factors pointing to a movement back to the engine for the average industrial plant.

Keeping Idle Generators Warm

Troubles in generator windings at voltages characteristic of large stations have in many instances been traced to moisture. This appears to be principally due to allowing the generator to become cold. Thus during the night it may reach a temperature somewhat lower than that of the room during the day. On being started up in the daytime, it encounters a rush of warmer air, and condensation on the windings immediately forms. This occasionally produces corona, even at low voltages. The final effect will be to increase the corona each time it occurs, until the winding breaks down.

To safeguard against such trouble, it is suggested by G. Munson, in the *Journal of the A.I.E.E.*, of April, that generators be maintained at slightly warm temperatures when idle. Steam coils or drafts of warm air may be utilized for this purpose.

Condenser Tubes Protected by Sea-Water Scale

The United States Coast Guard Department reports an interesting experiment with marine condenser tubes to counteract deterioration. It is stated that as a result of a suggestion recently made by the department to one of the large companies engaged in the manufacture of marine condensers, a sea-water coating is being used that bids fair to important results.

Based on the theory that tube deterioration is caused probably by oxidation, it was recommended that a non-soluble protective coating be secured on the salt water side of the tube. The best coating for this purpose was suggested to be sea-water scale. Accordingly, rather extensive experiments have been conducted along this line. Pieces of condenser tubes, immersed in clean sea water, have been treated until sufficient thickness of scale matured for the experiments. Oxygen was bubbled through the tubes while still immersed in the sea water, and over a considerable length of time no perceptible damage to the tubes is apparent.

How External Air Cooling Increases the Effectiveness of Condenser-Tube Surface

By Paul Bancel*

Two distinct processes ordinarily occur inside of surface condensers; namely, steam condensing, which goes on at a high rate of heat transfer, and devaporizing the air-steam mixture, which is carried out at a very low rate of heat transfer. The latter is necessary in order to reduce the volume of the mixture suitably for the vacuum pump. When air coolers are provided outside of the condenser to handle the latter process, the condenser tubes may operate at much higher efficiency.

THE main process of condensing steam, which occurs at a constant temperature, may be carried on at a comparatively high rate of unit heat transfer. Tests on single tubes by Orrok showed heat-transfer coefficients of 1,000 to 1,500 B.t.u. per square foot per hour, and in practice these rates are approached by some of the tubes in actual condensers.

In addition to this, residual vapor must be condensed out of the mixture of steam and air that is on its way to the suction of the vacuum pump. This occurs at a falling temperature, with rapidly increasing air concentration, which of course is the reason for the cooling. Here the rate of heat transfer is much lower, from less than one to ten B.t.u. per square foot per hour. This represents almost "dead" tube surface, when carried on inside of the condenser.

One of the problems in condenser design is, therefore, to eliminate or reduce these "dead" tubes that ordinarily do the air cooling.

If an external air-cooling device is employed, these inefficient condenser tubes are manifestly eliminated and the average rate of tube heat transfer increased. Thus, if the original condenser had two tubes, one of which was condensing steam and the other devaporizing air, the elimination of the second tube and internal devaporizing would double the average heat transfer. Such an external cooling device may be so designed as to be more efficient and economical of material than condenser tubes.

The condensing and air-cooling process is analyzed in Table I[1]. At the condenser one pound of the mixture has a volume of 657 cu.ft. at 79 deg. F. Steam is condensed at constant temperature (neglecting loss of pressure) in the first zone, where conditions are recorded at three points. Approximately 99 per cent of the heat is here abstracted.

In the remaining zone the temperature lowers steadily as the residual water vapor is condensed from the air-steam mixture. This is termed the cooling or devaporization process. It will be seen that the volume of the mixture drops from 8.2 cu.ft. to 0.16 cu.ft. This represents a final volume of approximately one-fiftieth of that before devaporization began.

Therefore, two distinct processes with distinguishing features occur in condensing steam:

1. Condensation—(a) Carried on at constant temperature; (b) high rate of heat transfer; (c) removes 99 per cent of the entire heat taken from the exhausted mixture.

2. Devaporization or cooling—(a) Results in falling temperature; (b) poor rate of heat transfer; (c) abstracts less than 1 per cent of the total heat removed.

When the devaporization is carried on inside of the condenser, it is found that a great many tubes are required and yet only a negligible amount of heat is absorbed. These tubes show practically no temperature rise for the circulating water. They therefore act very inefficiently. It is readily seen that when devaporization is carried on at low efficiency (such as 2 B.t.u. per square foot per hour, even for small amounts of heat, such as 1 per cent of the total), nevertheless, a large amount of cooling area is needed.

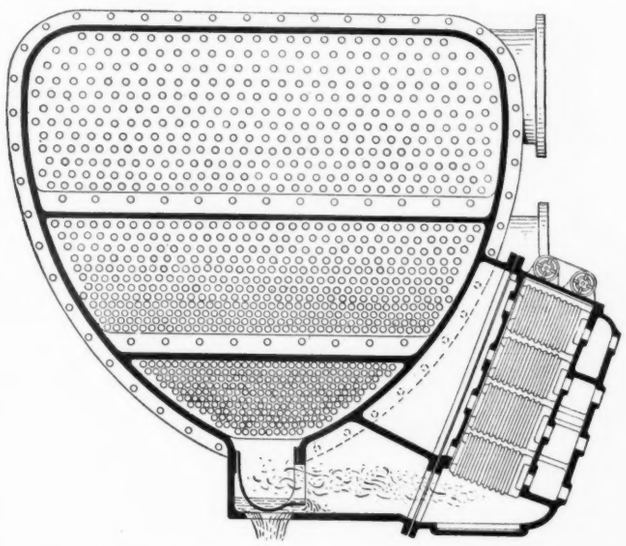


Fig. 1—Air-steam mixture devaporized by external cooler at right

Tests of the surface condensers aboard the "Tennessee" and the "Maryland," published in the *Journal of the A. S. N. E.* of November, 1922, show a very small rise of temperature in the first pass, which contains the air cooling tubes. A large rise occurs in the second pass, where the upper tubes are exposed to the steam from the turbine. The condenser aboard the "Maryland" at heaviest load showed from 0.6 to 2 deg. rise of the water going through the first pass, as against 16.3 and 14.5 deg. rise in the second pass. The "Tennessee" condenser indicated 3.8 deg. to 4.4 deg. rise in the first pass and from 12.7 to 15.3 deg. in the second pass. At light loads both condensers showed

*Condenser Department, Ingersoll-Rand Co.

[1]This table is taken from page 467 of a paper by M. C. Stuart and A. H. Senner, in the August, 1920, issue of the *Journal of the American Society of Naval Engineers*, and is in turn based on a paper by Gibson and Bancel, A.S.M.E. 1915, page 975.

zero rise in the first pass, indicating that practically all the work was done in the second pass.

One method of accomplishing the air cooling or devaporizing process externally to the condenser is indicated in Fig. 1. The exhaust steam first impinges on a wide cross-sectional area of cooling tube surface at the top. This sectional area gradually narrows toward the bottom of the condenser, where condensate and the air-vapor mixture are withdrawn. The condenser, therefore, is of a wedge or heart-shaped cross-section.

TABLE I—HOW STEAM IS CONDENSED AND AIR DEVAPORIZED IN A SURFACE CONDENSER

Showing typical action in a condenser supplied with one-pound of steam-air mixture, containing 0.0002 lb. air. The process of steam condensation and air compression at a constant vacuum of 29 inches, is illustrated.

	Condenser Entrance	Zones Inside Condenser: Steam Condensing Zone			Air Cooling and Compressing		Air Pump Suction
1. Temperature of mixture, deg. F.	79	79	79	79	76	72	59
2. Partial pressure of steam, in hg.	1.0	1.0	1.0	0.99	0.90	0.80	0.50
3. Partial pressure of air, in hg.	1/8000	1/4000	1/1000	1/100	1/10	1/5	1/2
4. Pounds of air present	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
5. Pounds of steam condensed	000	0.5000	0.8748	0.9873	0.9987	0.9993	0.99967
6. Pounds of steampresent	0.9998	0.4998	0.1250	0.0125	0.0011	0.0005	0.00013
7. Volume of air present, cu.ft. at partial press.	657	328	82	8.2	0.823	0.412	0.164
8. Volume of mixture, cu.ft. at total press.	657	328	82	8.2	0.823	0.412	0.164
9 Volume of mixture, cu.ft. per lb. air	3,285,000	1,640,000	410,000	41,000	4,115	2,060	820
10 Lb. of air per 1,000 cu.ft. mixture	0.0003	0.0006	0.0024	0.024	0.243	0.485	1.22

With large condensers two air coolers or devaporizers are required, one for each half length, while on small condensers only one is used. These are of different

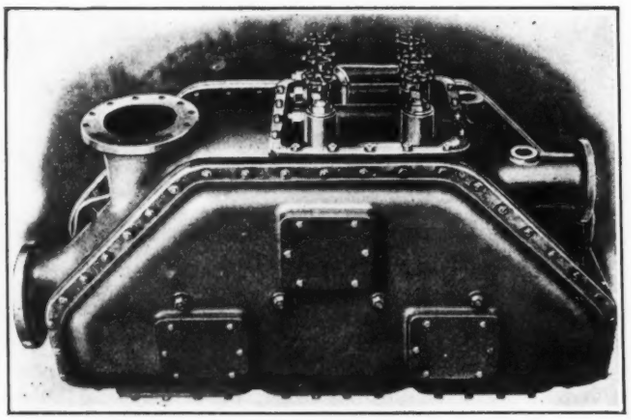


Fig. 2—Air withdrawn from top of wedge-shaped cooler

standard sizes depending on the capacity of the unit. Fig. 2 indicates the external appearance of this element and Fig. 3 is a bottom view with covers removed.

The heat-absorbing surface consists of cast-iron grids, as shown in Fig. 4. Circulating water passes through the cores of these grids. These are banked so as to provide a wedge-shaped cross-section, giving a steadily diminishing area during the flow of the mixture toward the outlet area at the top (see Fig. 2). In other words, the lower line of grids (Fig. 3), extends an appreciable distance along the condenser, the next upper row a shorter distance, and so on until at the top, where the air is withdrawn, only a few grids are placed. This represents the apex of the triangle as viewed standing opposite the side of the condenser.

The process of devaporization is not to be confused with air cooling such as in the intercooler of an air compressor or the ventilating system of an alternator. In these examples the weight of the air in circulation

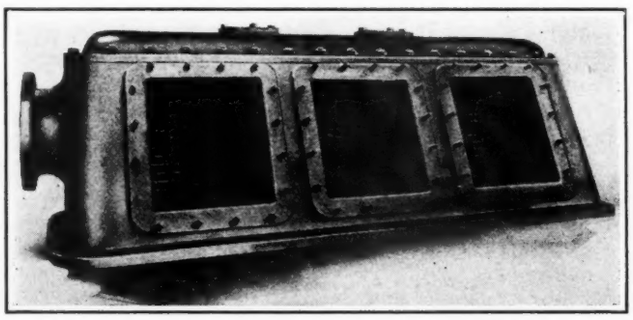


Fig. 3—Wide grid surface at bottom of cooler

is constant; the weight of the mixture entering is the same as that of the mixture discharged.

Condenser devaporizers, however, receive a mixture of steam and air which must be shrunk in volume largely by condensation. A much greater weight of vapor must be received than is discharged. In Table I it will be seen that through the air-cooling zone the volume is reduced approximately one-fiftieth. This process may be roughly compared to that of fractional distillation. The steam is left behind and the air, with as little vapor as possible, is discharged to the vacuum pumps.

A great difficulty is to prevent hot streaks of vapor passing through and going to the vacuum pump, while leaving the air behind. The grid construction in these air coolers gives a large amount of surface for devaporization, or sweating the moisture out of the mixture, and at the same time breaks up the flow of the vapor and prevents hot streaks contained in it from going directly to the vacuum pump. The devaporizing grids, Fig. 4, are of unfinished cast iron with rough surfaces. They present considerable frictional resistance and maintain the mixture in a turbulent condition.

TABLE II—TEST OF 10,000-KW. CONDENSER WITH EXTERNAL DEVAPORIZERS

Tube surface, 8,430 sq.ft.

Date	July 22	July 30	July 31	Sept. 23	Oct. 1
Kilowatts	10,600	10,500	11,400	7,050	10,700
Injection temp., deg.	78.1	70	68.7	70	65.3
Average discharge temperature	88.8	80	79.4	77.1	76.1
Vacuum 30 in.	27.77	28.37	28.26	28.62	28.45
Steam temperature	104.8	94	96.6	89.3	92.3
Condensate temperature	102	90	93.0	91.1	88.8
Load pounds per hr.	142,000	138,000	148,200	96,500	141,500
Load per sq.ft.	16.7	16.2	17.4	11.4	16.6
Vacuum correct to 70 deg.	28.27	28.37	28.18	28.62	28.2

EXTRACTS FROM OTHER TESTS

Load, kw.-hr.	11,520	6,000
Injection, deg. F.	78.2	78.5
Average discharge	90	85
Bottom discharge	90.6	84.5
Average rise	11.8	6.5
Bottom rise	12.4	6.0

The effect of external devaporizing in a 10,000-kw. condenser is indicated in Table II. The temperature of the discharge water from the bottom section and the high temperature rise in the lower part of the

table prove that these last tubes are actively condensing steam at a high rate. Thus in the tests of July 22 it is seen that temperatures are: Injection, 78.1 deg.; average discharge, all water, 88.8. Other readings taken at this time are: Bottom discharge, 89.8; average rise, 10.7; bottom rise, 11.7.

In this case the load was heavy and the bottom heated actually more than the top, this being possible by reason of the lower water velocity in these tubes. Extracts from other tests on the 22d show the same excess rise at heavy loads and practically full rise at 60 per cent load, also given in Table II.

This high degree of activity of the last tubes is due largely to the use of the external coolers. The practical

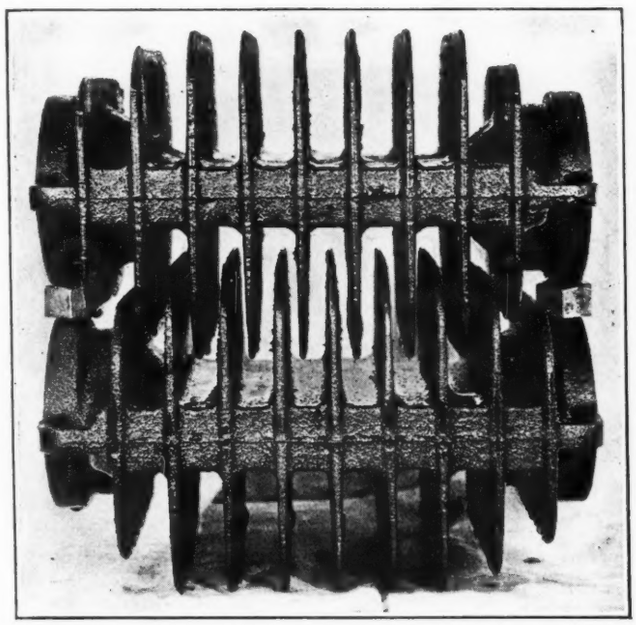


Fig. 4—Rough cast-iron grids maintain a turbulent flow of air-vapor mixture

result of making all the tubes effective in condensing steam is to increase the loads per square foot by 100 per cent over older types. In other words, the surface used is half that required in older designs.

Ordinarily, the pump power to give high velocities and attendant higher heat transfer per tube would be excessive, but once the design has been developed for making all tubes active, the water circuit can be rearranged for the high velocity in single pass instead of two pass, thus reducing the friction.

Part of the large gain in efficiency is due to using higher water velocities in the main tubes, but this, in turn, is made possible by design and the elimination of waste. The combined effects multiply. Thus if there is an improvement to 150 per cent in efficiency of using the tubes and 150 per cent in heat transfer of each tube, the total improvement is about 300 per cent.

Even when air devaporizers relieve the condenser of the worst of the air effects, the lower tubes cannot be expected to work as efficiently as those on top. The steam that reaches the lower tubes is necessarily colder than the incoming steam, as there is a loss of pressure in passing through the tube spaces. This is minimized by the arrangement of the tubes, but it is nevertheless a finite amount.

In the second place there is a falling off in the effectiveness of the lower tubes, on account of some air which is now in a more concentrated state than in the upper part of the condenser. For these reasons the water is concentrated at higher velocity in the top tubes of the condenser of Table II and at a lower velocity in the lower, as shown in Fig. 1.

This works out to advantage with air devaporizers, as the cooling water is used over again in the lower condenser tubes. The circuit is thus two-pass and counterflow in effect as regards the devaporizers and the lower tubes. The water velocity is automatically reduced in the bottom tubes as required. There is practically no heating of the water in the coolers, which is desired as the lowest temperatures are here required.

Some engineers have felt that while the older designs of condensers contained twice the tube surface, this represents a reserve capacity not found in the later type condensers with less tube surface. This matter will be discussed in a succeeding article.

Flywheel Explosion at Hudson, Mich.

Details are now available of a flywheel explosion that occurred recently in the plant of the Southern Michigan Power Co., at Hudson, Mich. The accident occurred to a tandem-compound engine with cylinders 14x28x36-in. and a speed of 110 r.p.m., belted to an alternating-current generator. On the opposite end of the shaft the generator had a small pulley that carried a belt for driving the exciter, making one complete unit. The machine had been in service for about six years. At the time of the accident it was carrying all the load, and the trouble originated from the exciter belt running off the pulley. This caused the generator to drop its load, and the shaft governor failed to control the engine.

The plant is close to the Cincinnati Northern Railroad, and at the time an engine was doing some switching near the plant. Owing to the noise made by the switching engine, the operating engineer, who does his own firing and was standing in the boiler-room door, failed to notice any unusual disturbance in the engine room. Upon turning around, he saw that the engine was gaining in speed and attempted to close the throttle, but before he had time to do so, the belt wheel burst. This wheel was of the thin-rim type made in two sections with the rim held together by flanged joints. Owing to the extra weight of the joint at the weakest point of the rim, this type of wheel has the lowest factor of safety of any of the general designs in common use. It carried the belt driving the generator and in the accident was completely wrecked. All the pieces went forward from the engine, some striking the generator frame and breaking a large piece out of the base, and others wrecking the switchboard, making holes in the roof and the brick wall of the station. The wheel was 14 ft. in diameter, 28-in. face and weighed 12 tons.

The mainshaft of the engine was thrown out of its bearing, breaking the lower part of the bearing from the engine frame on the crank end and the outboard bearing below the shaft. The connecting rod pulled loose from the crank pin and other reciprocating parts of the engine were badly damaged.

According to the engineer, the exciter belt had come off several times in the past and the engine had speeded up, but always it had been possible to close the throttle before any damage had been done. In the present case, the total loss is estimated at $25,000, on which no insurance was carried.

Converting a Loser into a Profit-Making Plant

A MISSOURI central station supplying both electricity and ice cut its generating cost from over six to less than one cent per kilowatt-hour by replacing an obsolete steam plant with Diesel engines. Waste heat recovery is employed in nearby house heating service.

DID you ever have a lot of machinery costly to operate yet in too good mechanical condition to junk? Did you ever wish that a fire, tornado or earthquake would solve the problem, even though little or no insurance was carried? This was almost the situation of the Arkansas & Missouri Power Co. in 1922, with respect to its Caruthersville, Mo., electric-light plant, as this plant had outlived its usefulness.

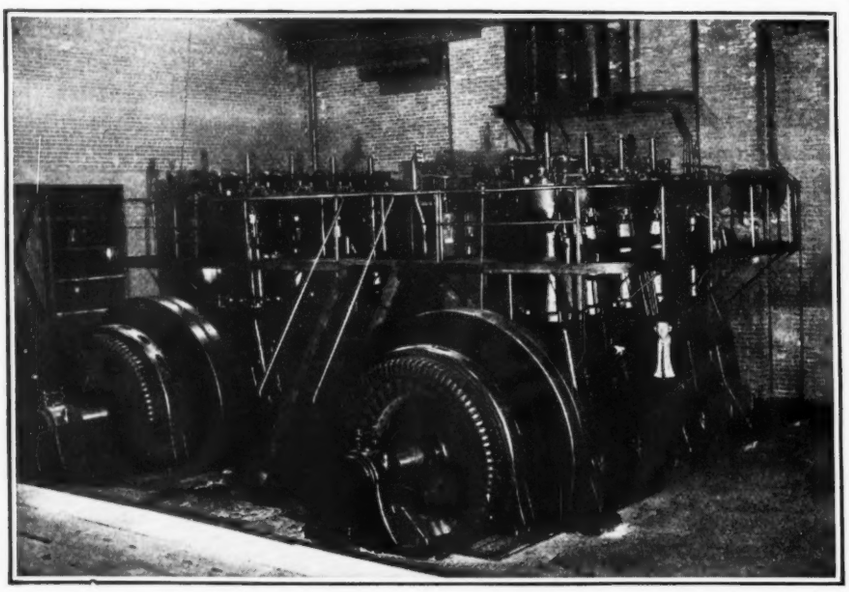


Fig. 1—The two 400-hp. Diesels

The plant combined an electric lighting and an ice-making department, the power being steam. Two vertical two-cylinder single-acting compressors served the ice plant, the units being driven by horizontal single-cylinder steam engines whose frames were bolted to the compressor frames.

In the light-and-power end of the plant were two steam engines. One was a girder-frame Corliss belted to its alternator, and the second, a direct-connected four-valve machine. Steam was supplied by water-tube and horizontal-tubular boilers. The system had been installed when coal and labor were cheap. In their time the engines were no doubt efficient, but high prices had made the operation of the plant a costly affair. Income was seldom more than one length ahead of expenditure.

As a result of a fire the plant was destroyed and the decision of the management was to install modern high-efficiency Diesel engines, at the same time putting in a raw-water system of ice making. While awaiting the delivery of the engines, it was necessary to put the damaged machinery into operating condition in order to make the discontinuation of electric service as short as possible, inasmuch as the plant served three towns.

A wooden shed was thrown up over the old engine room, and after a short interval service was renewed. The construction of the new building proceeded, the new walls and roof being carried around and over the temporary shed. As the new machinery arrived, it was placed in its proper position and on Jan. 18, 1923, the new Diesels were started and the old steam units were definitely put out of service.

In Fig. 1 are shown the two 400-hp. Diesels, each being direct connected to 280-kw. 2,300-volt three-phase 60-cycle alternators. The exciters are belted from a pulley on the engine shaft. These units operate on continuous 24-hour schedule and are shut down every other Sunday for inspection and adjustment.

The underlying soil throughout the delta in Southeastern Missouri is locally called "loblolly," being a thick black mud. In putting in the foundations it seemed advisable to make both engine foundations as one unit in raft form. This gave a large bearing surface and is superior to a deeper construction of less ground area. While each engine was as closely balanced as possible with crankshaft having all four crank throws in a single plane, the character of the soil permitted vibrations to be set up at some distance from the plant. As a solution the two generators were so arranged that they could be synchronized when the crank-throw planes of the two engines' crankshafts were 90 deg. apart. In this way the unbalanced forces of one shaft dampened the vibrations set up by the unbalanced forces of the other shaft. So successful is this arrangement that the vibrations so noticeable in certain dwellings a mile away have disappeared entirely. This same dampening effect could be used in many plants having two or more oil engines.

Several devices are used that should find a more general application. A number of houses in the same block as the plant are equipped with hot-water heating systems. A small motor-driven centrifugal pump picks up water from the returns sump and forces it through a coil in the engine exhaust muffler. To increase the amount of waste-heat recovery, the water is then passed through the jackets of the exhaust manifold; a special jacketed section is used in place of the usual unjacketed pipe beyond the engine. The water then flows through the heating mains to the houses, an overhead tank maintaining a uniform head on the lines. The heat-recovery coils are by no means as efficient as a waste-

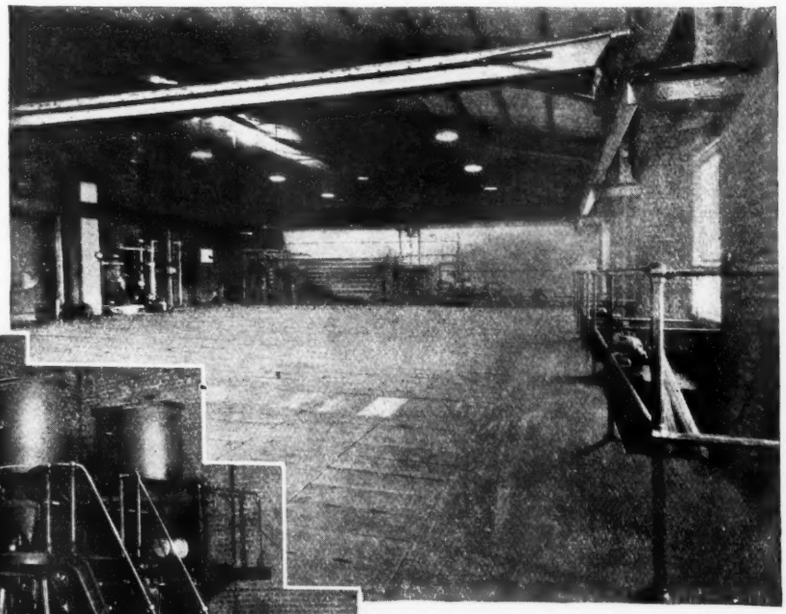


Fig. 2 (below)—Ice machines converted from steam direct drive to belted motor drive

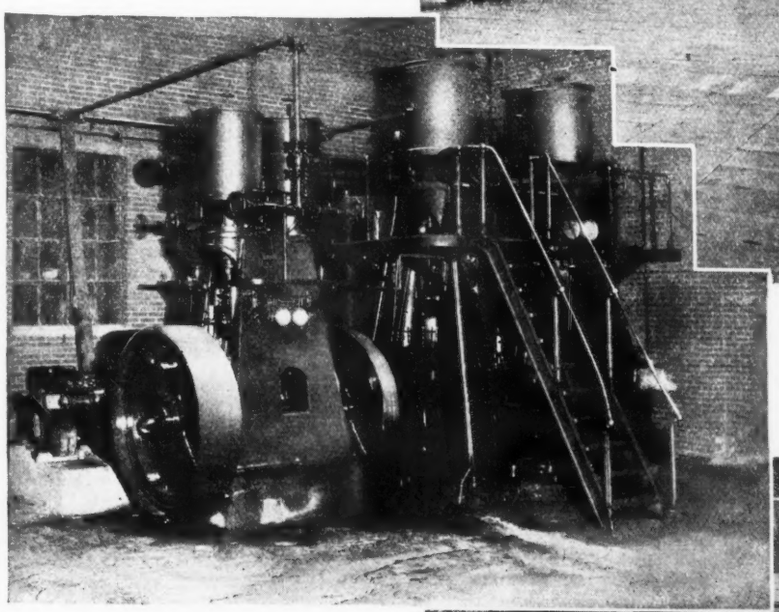


Fig. 3 (above)—Brine tank contains 490 three hundred pound cans

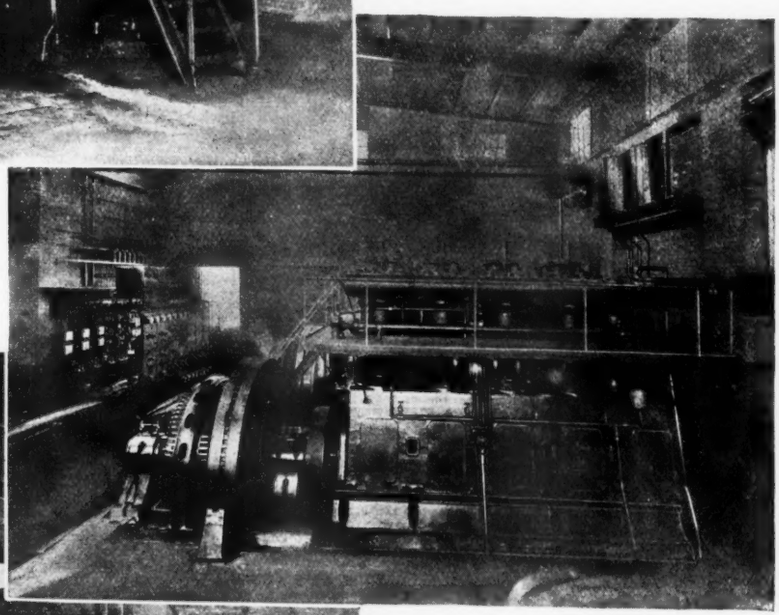


Fig. 4 (right)—View of 400-hp. engine showing trolley crane above machines

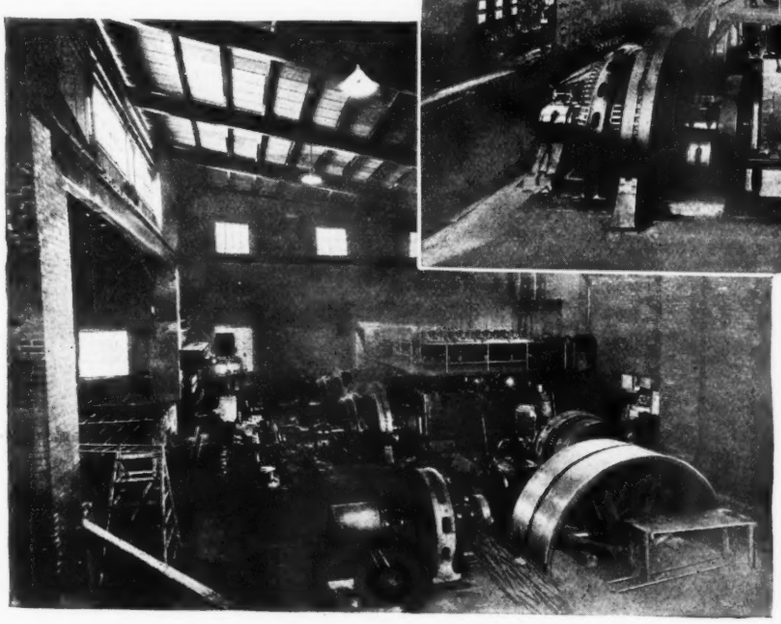


Fig. 5 (left)—Engine room during erection of the Diesel units. Parts of old machines in foreground

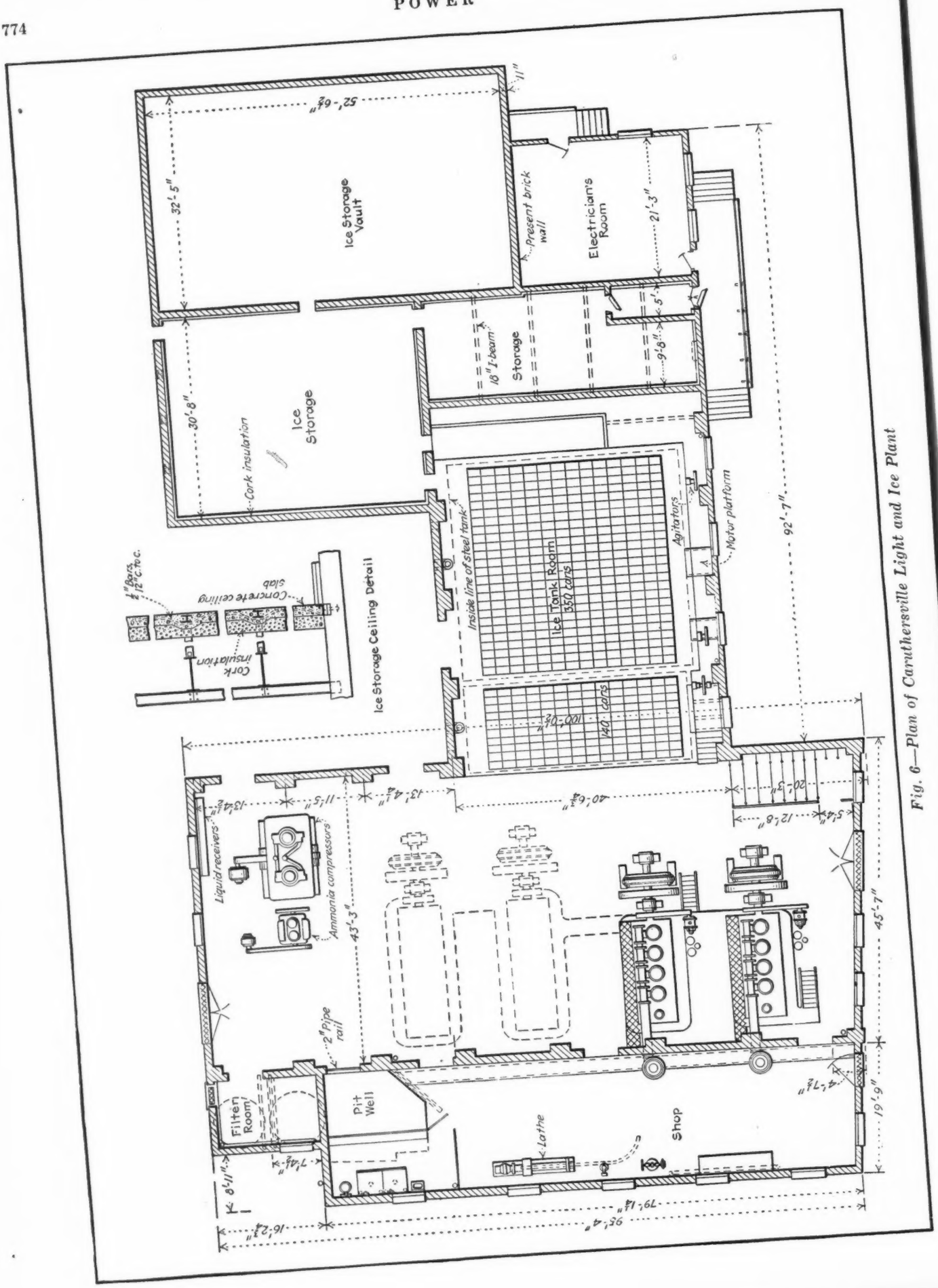


Fig. 6—Plan of Carmthersville Light and Ice Plant

heat boiler, but are ample to meet the requirements of the several houses.

The engines are equipped with a gravity-feed stream lubrication system for the bearings. The oil drops into the crankcase and a pump, direct-driven from the engine shaft, puts it through a filter which removes any dirt

GENERATION COST

	Steam	Diesel
Boiler room	$375.00	0
Fuel oil	0	$851.20
Unloading coal	20.00	0
Coal	2,563.36	0
Wages, including ice pullers	444.95	287.77
Lubrication, waste, etc.	158.77	175.15
Total	$3,561.98	$1,314.02
Maintenance		
Building	0	$21.47
Boilers	$36.75	
Engines, including spares	9.40	356.40
Tools	10.51	.82
	$3,618.64	$1,692.71
Kw.-hr.	60,000	181,420
Production cost per kw.-hr., cents	6.3	.94

that might be present. The fine carbon, however, cannot be eliminated by filtration through cloth; consequently, a chemical reclaimer is used. At stated intervals part of the oil is put into the reclaimer tank and heated, as well as washed with water. This is

DATA ON EQUIPMENT IN CARUTHERSVILLE PLANT

Engines	Diesel
Manufacturer	McIntosh & Seymour Corp.
Type	Four-stroke-cycle
Number	2
Capacity of each horsepower	400
Revolutions per minute	200
Cylinder size, in.	16½x24
Brake M.e. p. lb. per sq.in.	77.1
Generators	
Type	3-phase, 60-cycle, 2,300-v.
Manufacturer	Allis-Chalmers
Number	2
Capacity, kw. each (80 per cent P.F.)	280
Exciters	
Manufacturer	Allis-Chalmers
Capacity, each, kw	17½
R.p.m.	1,100
Voltage	125
Oil Filter	Richardson-Phenix
Oil Reclaimer	De La Vergne
Ice Machine	
Manufacturer	Frick Co.
Number	2
Capacity, tons	1—40 1—90
Drive	Lenix short Belt
Motors	Wagner
Horsepower	1—75 1—40
Air Compressors	
Type	Single Cylinder Double Acting
Manufacturer	Pennsylvania Pump & Compressor Co.
Number	2
Cylinder size, in.	9x6
Discharge pressure, lb. per sq.in.	25
Drive	Belted from motor
Make of motor	General Electric
Horsepower	15
Speed	1,140
Voltate	220
Phase	3
Agitators	
Number	2 Propeller type
Manufacturer	Frick Co.
Drive	Belted to motor
Make of Motors	Allis-Chalmers
Horsepower	3
Speed	1,140
Voltage	220
Car Dump, Make	York
Dehumidifier	York
Water treatment system	International System
Pump	Gardner Duplex
Drive	Belted to motor
Motor	7½ hp. 220 volt Allis-Chalmers
Sump dump	Air driven Marsh Duplex

followed up by treating with a compound consisting of approximately 84 per cent sodium carbonate and 3 per cent sodium hydroxide the remainder consisting of various chemical neutrals.

Cooling water is obtained from a well inside the building and located at the bottom of a pump pit. Since the water is comparatively free from a mineral that will form scale at the jacket temperatures, treatment is not required.

Comparative Results Obtained

The results obtained through the installation of the Diesel engines compared to the costs with the old steam-engine are given herein. These costs are for the months of November, 1923, with Diesel power and November, 1922, when steam was used. The high cost of 6.3c. per kw.-hr. explains why many coal-burning central stations of medium capacity are finding continuation of service a serious problem. The fuel oil used in the Diesels cost 3.8c. per gal. This is higher than the market price of suitable oils, but the management felt that only the highest-grade fuel should be used the first year.

As has been mentioned, the steam ends of the ice machines were removed, electric motors with short drives being substituted. By overhauling and speeding them up, production was increased from 28 to 45 tons per day with the same tank, consisting of 490 three hundred pound cans. This tonnage is unusual for this size tank, but in this plant the force is able to freeze clear ice without cracking with six-degree brine, allowing only 11 cans per ton, while 16 cans per ton is the usual recommendation.

The brine-tank layout is shown in Fig. 6. As raw water is used in ice making, a treating system was required. The chemical mixing tank is on the roof of the treating room. The condensers are of the atmospheric type, the cooling water being supplied by the pump in the well pit. The liquid receiver is placed in one end of the engine room and is arranged for purging, so that the old wasteful method of eliminating foreign gases by purging at the condenser top is avoided.

Fig. 6—Plan of Caruthersville Light and Ice Plant

Several Stations Adopt Reheating and Extraction Cycles

The confidence with which large stations are adopting both the extraction and reheating cycles, together with high pressures and temperatures, indicates faith in builders and designers to handle successfully new conditions where risk and expense are involved.

Large units are characteristic of the Crawford Avenue Station, Chicago, which will contain two 50,000-kw. turbines and one 60,000 operated at 550 lb. 725-deg. steam and reheating the steam at approximately 100 lb. to the initial temperature. Feed water is heated by extracting from the turbine and heating to approximately 300 deg. F.

One station is being constructed by the American Gas & Electric Co., in which there will be four 35,000-kw. 1,800-r.p.m. turbines, and the other two stations, one being contemplated, will each have two 35,000-kw. turbines. All will be operated under the same steam conditions as the Crawford Avenue plant. The Columbia Gas & Electric Co. is building one station, with two 40,000-kw. 1,800-r.p.m. turbines under similar steam conditions.

An impulse unit of 3,500 kw. receiving steam at 1,200 lb. 725 deg., exhausting at 350 lb. pressure, will be operated by the Edison Illuminating Co. of Boston, at its Weymouth station. Reheating will be carried out to 725 deg. A somewhat similar installation is being planned for try out at Calumet.

Davis Bridge Development of the New England Power Company

Project on Deerfield River involves an earth dam 200 ft. high, storage reservoir of 50,000,000,000 cu.ft. capacity, a 13,000-ft. tunnel and three 20,000-hp. units for a head varying from 300 to 390 feet.

IN DRY seasons there is little to indicate that the Deerfield River could be converted into one of this country's important sources of hydro-electric power. During low-water periods it is not much more than a good-sized swiftly running brook and can be crossed almost anywhere without getting one's feet wet, except at the site where power is being developed, by walking on the rocks in the river's bed. But when the New England Power Co. has completed its development on this river, there will be produced nearly 400,000,000 kw.-hr. annually and 110,000 kw. in generating capacity will be installed. The river rises in south central Vermont and flows into the Connecticut River at Greenfield, Mass. Its total length is 80 miles, and it has a drainage area of about 550 square miles. Although there are no abrupt drops in the river, it has a comparatively steep gradient throughout its length, which results in a total

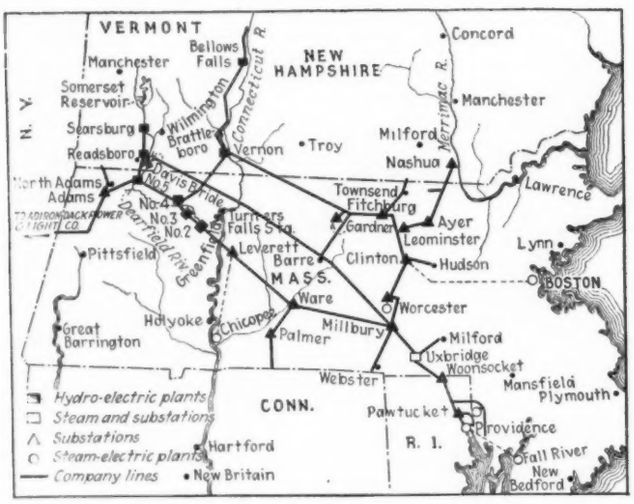
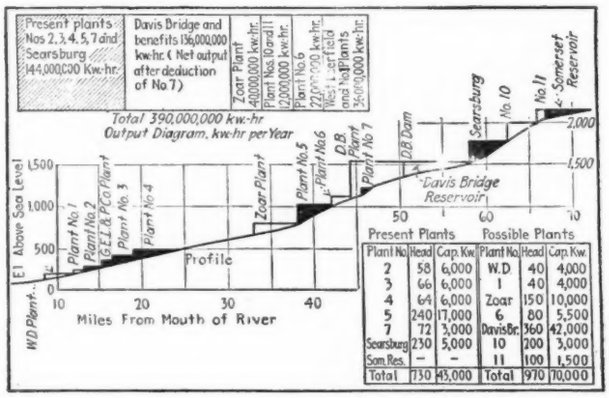


Fig. 1—Heavy lines indicate system of New England Power Company and dotted lines show connections to existing steam plants

fall of over 2,000 ft. (see Fig. 2). At the upper end for over 50 per cent of its length the river flows between steep banks, and as this region is sparsely settled, the location is ideal for water storage. In this lies the secret of the large power possibilities of the river. When the present developments are completed, it will be one of the most highly utilized streams for its drainage area in the Eastern States and one of the most complete examples of water-power development in the country.

The largest development on the river, known as Davis Bridge, is nearing completion and will operate under a head varying from 300 to 390 ft. and develop 60,000 hp. A storage reservoir with a capacity of 50 billion cubic feet is part of this development. This reservoir, combined with the Somerset reservoir at the head of the river, which has a capacity of 2½ billion cubic feet,



Plant No.	Head	Cap. Kw.	Plant No.	Head	Cap. Kw.
2	58	6,000	W.D	40	4,000
3	66	6,000	1	40	4,000
4	64	6,000	Zoar	150	10,000
5	240	17,000	6	80	5,500
7	72	3,000	Davis Br.	360	42,000
Searsburg	230	5,000	10	200	3,000
Som. Res.	–	–	11	100	1,500
Total	730	43,000	Total	970	70,000

Fig. 2—Profile of Deerfield River

When power developments are completed on the Deerfield River it will be one of the most highly utilized streams in this country, with a drainage area of 550 sq.mi. it will produce about 400,000,000 kw.hr. annually.

will convert the river into one that has practically a constant flow although originally it was very flashy.

There are many features about the Davis Bridge development that make it stand out as one of the interesting and important water-power projects in the eastern part of the country. First, the earth dam and storage reservoir, on account of their size, are of special interest. In this section of the country, materials suitable for the construction of earth dams are available, and this was one of the chief reasons for selecting this type. The dam is probably the highest of its type in the world (see Fig. 3). In the construction of such a dam the flow of the river must be bypassed. This was done by driving a diversion tunnel, having a cross-sectional area equal to a circle 22.5 ft. in diameter, around the dam in the rock on one side of the site.

Conditions were not favorable for the construction of a spillway in the dam except at excessive cost. In this the diversion tunnel helped solve the problem, as it was found that part of it could be used as conduit spillway, Fig. 4. The intake to this spillway is about 350 ft. upstream from the center line of the crest to the dam. On the side of the river where the spillway is located, there is rock formation in which a suitable intake could be cut. The entrance to the spillway is shaped like an inverted horn 160 ft. in diameter across the mouth, which gradually contracts into a vertical circular shaft that extends down and enters the diversion tunnel. This spillway was proposed and the detailed design worked out by the engineers of the J. G. White Engineering Corp., consulting engineers for the project.

Around the circumference of the spillway's mouth there are 16 radial concrete piers which will serve the

double purpose of carrying a bridge from which flashboards can be operated and directing the flow over the crest of the spillway. After the dam was completed, the diversion tunnel was closed with a concrete plug above where the spillway enters. Through this plug a 48-in. cast-iron pipe was placed, primarily to carry stream flow during the placing of the concrete. A 48-in. valve was placed at the same time and after closing this a reducing section, with a 36-in. valve and steel discharge pipe, was installed to bypass water around the dam.

The intake, Fig. 5, for the tunnel that conducts the water from the reservoir to the power house is about 300 ft. upstream from the center line of the dam's crest. The waterway in the base of intake tower is divided into two sections to connect with 8-ft. circular disk-arm type valves operated by motors mounted directly above and supported by the valve housings. As the bottom of the intake is about 110 ft. below maximum water level

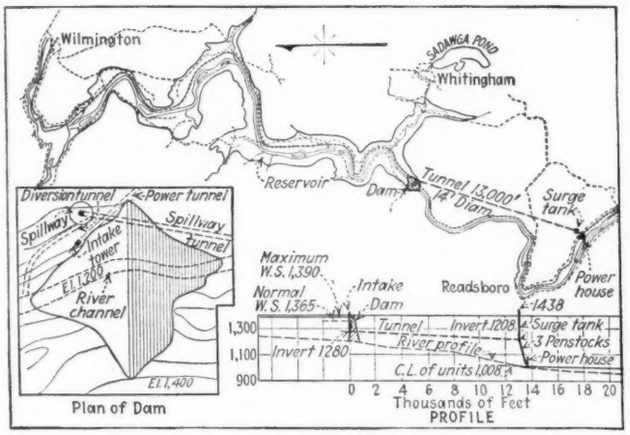


Fig. 3—Davis Bridge hydro-electric project

This earth dam is the highest in the world, having a height of 200 ft., is 1,300 ft. wide at the base, 1,250 ft. long at the crest and contains about 2,000,000 cu.yd. of material. A reservoir 10 mi. long is formed which covers 2,200 acres and has a capacity of 115,000 acre-feet.

of the reservoir, it was desirable to provide access to the valves through a dry tower. The valves are installed so that either one may be removed and the plant operated through the other, with only a temporary shutdown of the plant while bulkheads are being placed on each side of the valve housing.

The tunnel, which is 13,000 ft. long, is cut in solid rock and is lined with a minimum thickness of 6 in. of concrete. It is of horseshoe shape, having a width at the bottom of 14 ft., and is 13 ft. high. Owing to the maximum height of the water in the reservoir and the slope of the tunnel, its outlet will be subjected to a static head of 155 ft. and a probable surge head of about 200 ft. A ½-in. steel-plate lining to stand this bursting pressure is used for 320 ft. at the outlet end of the tunnel. This plate-steel lining terminates in a three-branch manifold, Fig. 8, to which the penstocks connect.

A surge tank of the Johnson differential type connects to the tunnel just back of the manifold. This tank is 34 ft. outside diameter and 184 ft. high, with an internal riser 8 ft. in diameter. As construction conditions were not favorable for placing the tank directly over the tunnel, it was located 40 ft. to one side, where a suitable foundation could be constructed. A plate-steel 90-deg. bend 10 ft. in diameter connects the middle of the bottom of the tank with the tunnel lining.

An 8-ft. disk-arm valve connects each of the 9-ft. penstocks to the manifold, which is on a shelf in the cliff 240 ft. above the river's level. Just below the disk-arm valve is a 24-in. air valve on top of the penstock to vent the pipe when the valve is closed. Only two of

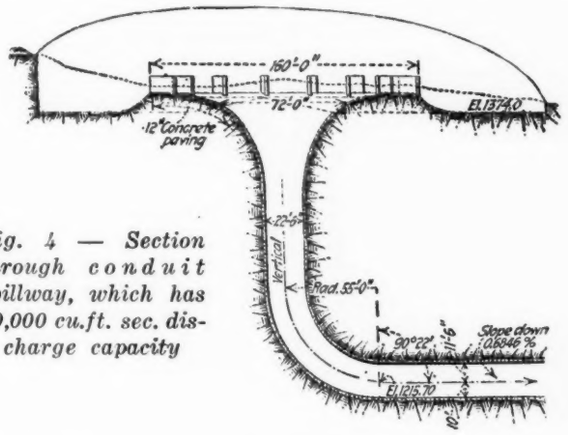


Fig. 4 — Section through conduit spillway, which has 30,000 cu.ft. sec. discharge capacity

the penstocks are installed at present. A third unit will be installed at some future date when the load demands make this necessary.

The disk-arm type valve, a modified form of a butterfly type, was developed especially for this installation by E. A. Dow, mechanical engineer of the company. These valves have an arm cast integral with the disk on the downstream face, to which the operating force is applied by means of a rod passing through a stuffing box in the valve housing, and is motor operated, controlled from the power house. The closing thrust is applied in such a way as to offset the tendency of the disk to distort under water pressure, thus increasing the tightness. The valves are of cast steel throughout,

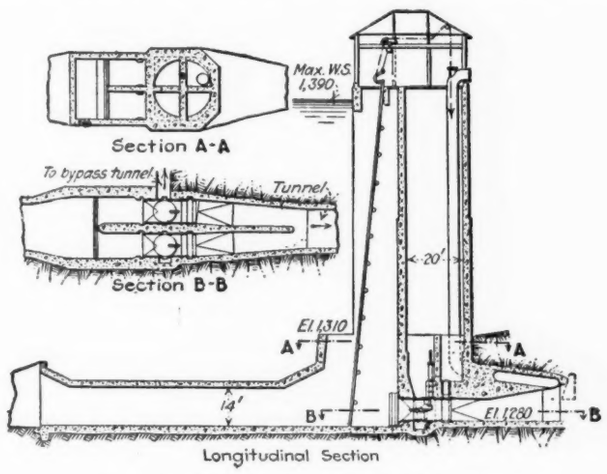


Fig. 5—Section through intake tower

Trash racks are 110 ft. long by 22 ft. wide and extend for the full length of the tower. Intakes to the tunnel are through two 8 ft. disk-arm type valves.

and the bodies are provided with babbitt seats which are non-corrosive and easily repaired in place if damaged.

In designing the penstocks, the maximum pressure that could occur with a two-second governing was calculated and the thickness of the plate made such as to limit the fiber stresses to 16,000 lb. per sq.in. To this thickness, $\frac{1}{16}$ in. was added to allow for corrosion. The

plates used in the penstocks have an elastic limit of 39,000 lb. and an ultimate fiber strength of 62,000 lb. per square inch, as shown by laboratory tests.

The entire hydraulic equipment, consisting of the plate-steel spiral-case turbines, plate-steel hydraucone draft tubes, integral type oil-pressure governors and the 84-in diameter hydraulically operated cast-steel butterfly valves, was designed and built by the Allis-Chalmers Manufacturing Co. The turbines, two of which have been installed, are each rated at 19,500 hp. under a 345-ft. net head and 360 r.p.m. These turbines established a record for the use of riveted plate-steel spiral casings. The highest head for which this type of casing had been used prior to this installation, was 240 feet.

Fig. 6 shows a sectional elevation through one of the turbines. By constructing the entire draft tube of plate steel, reinforced so that it does not vibrate, it can be easily grouted in at the upper part, thus saving a large amount of complicated form work in the concrete. This was particularly desirable in this case because of the necessity of getting this part of the work done as rapidly as possible. Since these turbines will sometimes be used as synchronous condensers—that is, for improving the power factor—and will be allowed to float on the line without using any water, the upper part of the hydraucone is provided with quick-opening vent valves for admitting air. Another feature of the installation is the wide range of head that the turbines must operate under, 300 to 390 ft., which is due to a 90-ft. draw-down in the reservoir.

One of the interesting parts of this installation is the plate-steel spiral casing. The inlet of the casing where it bolts to the butterfly valve is 84 in. in diameter, constructed of 1-in plates. All joints are double-riveted, and where the casing joins the speed ring, triple riveting is used for added strength. After the casings were riveted up, pressure tests were made by using a special test head to seal the inside of the speed ring and closing the butterfly valve on the inlet end of the casing. The latter was calked with lead from the inside to make it tight against reverse pressure. Although the normal operating head is 345 ft., or about 150 lb. per sq.in., a test pressure 260 lb. per sq.in. was applied. Minor leaks occurred around a few of the rivets, but were easily calked, after which the casing held the pressure for 24 hours with the rivets remaining dry.

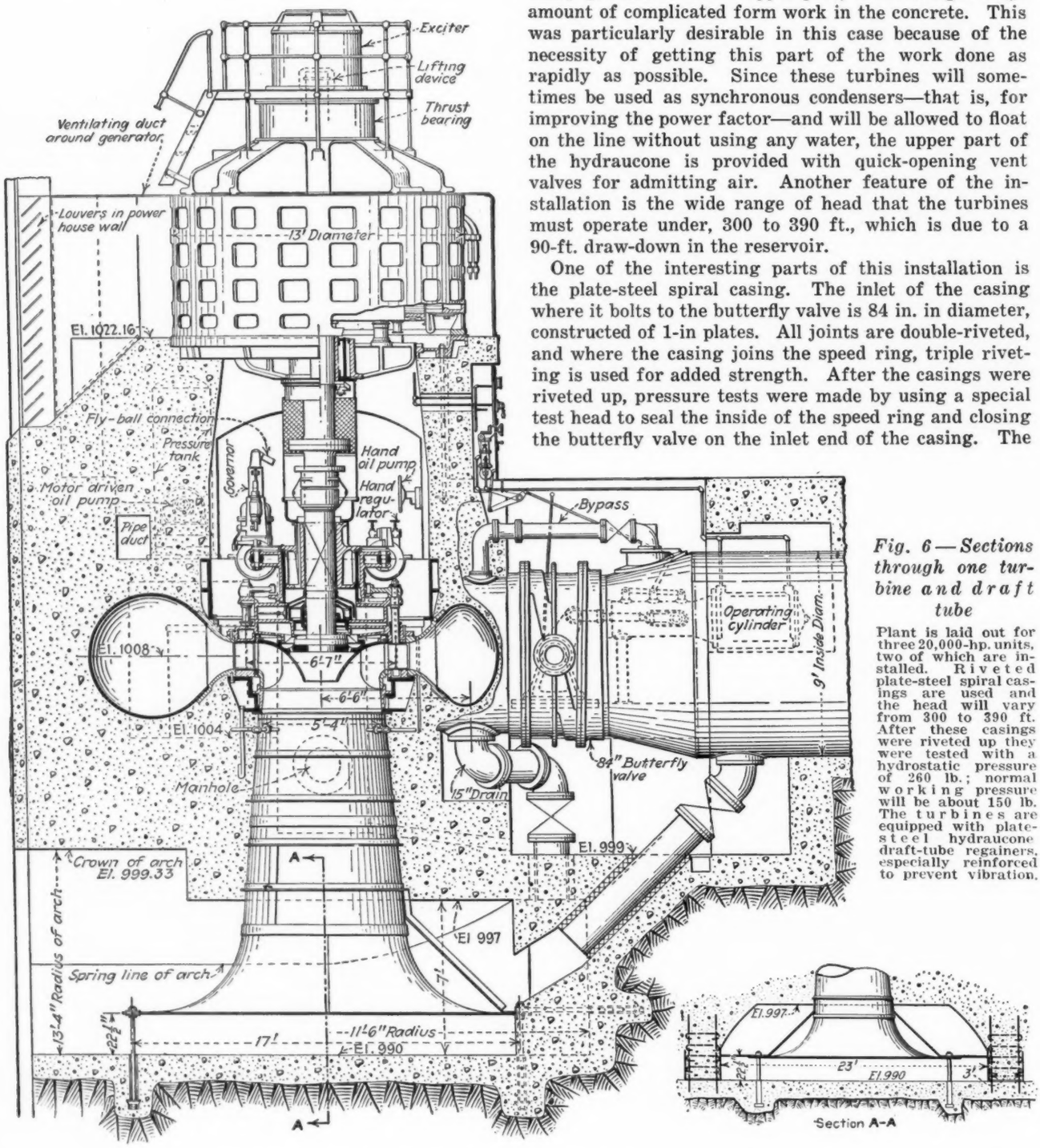


Fig. 6—Sections through one turbine and draft tube

Plant is laid out for three 20,000-hp. units, two of which are installed. Riveted plate-steel spiral casings are used and the head will vary from 300 to 390 ft. After these casings were riveted up they were tested with a hydrostatic pressure of 260 lb.; normal working pressure will be about 150 lb. The turbines are equipped with plate-steel hydraucone draft-tube regainers, especially reinforced to prevent vibration.

For these turbines the runners have special renewable steel wearing rings, shrunk on to the outer bands so that in case of wear such as would occur with dirty water, these bands may be renewed and thus the original clearances restored. To keep the leakage between the

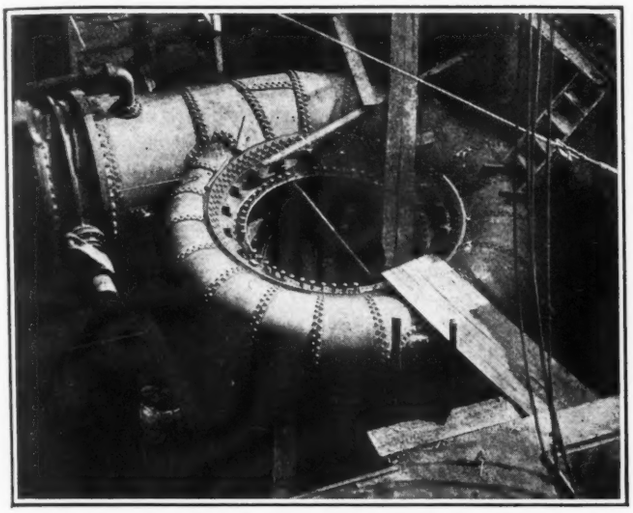


Fig. 7—Turbine casing connects to penstock through a 7-ft. butterfly valve

revolving and stationary parts as small as possible, special labyrinth seals are provided.

The main steady bearing of the turbine is of the babbitted, oil-lubricated type. An oil reservoir is provided in the cover plate and a small pump in this reservoir lifts the oil to the top of the bearing whence it runs down around the shaft. Special packing boxes are provided between the bearing and the runner so that water will not come up into the oil and also so that the suction from beneath will not draw the oil out of the bearing.

Governors of the integral type with the flyballs mounted directly on the mainshaft are used. Two regulating cylinders on each turbine are connected to the shifting ring, one at each side. The governor stand is on one regulating cylinder and the hand-control valves and hand pump on the other. The governor-control stand contains practically all the adjustments and controls, so that the unit may be started up, synchronized, set at any gate opening or position and locked or shut down by the attendant. Special electrical controls are so connected that the operator on the switchboard can perform these same duties. To accomplish this, a synchronizing motor is used, by which the gates may be opened, the turbine brought up to speed, synchronized and shut down. A special emergency shutdown device is also provided. The closing of a small contact switch on the switchboard energizes a solenoid mounted on the governor, which lifts a small pilot valve, admitting oil under pressure into a small cylinder which immediately lifts the pilot valve to the full-closed position and holds it there. This lets oil under pressure into the closing side of the regulating cylinders, moving the guide vanes to the full-closed position. This will close the turbine gates entirely in about two seconds and is very desirable in case of electrical or bearing trouble, where a slow shutdown might cause considerable damage.

Special bronze sealing rings operating similarly to the piston rings in an engine, are used around the edge of the disk in the butterfly valves in order to prevent leakage when in the closed position against a gross static head of 390 ft. The valve housing and disk are of cast steel, and cast-steel flanges are provided for riveting to the spiral-casing inlet and lower end of penstock and for bolting to the valve body. Renewable bronze seats are provided in the valve housing where the disk seats, so that in case of wear these may be replaced and the original tightness restored. The valve is opened and closed by using water from the penstock in a 24-in. diameter bronze-lined cylinder.

The generators, built by the General Electric Co., are rated at 16,000-kva. and are mounted on pedestals extending above the main floor with arched openings to the wheelpit. This gives a spacious arrangement in the plant and makes for operating convenience. A steel housing will surround each generator and be connected to outdoors, so that in the summer months the heated ventilating air can be discharged outside the station and in the winter time it can be turned into the plant for heating. The 6,600-volt current goes to an outdoor transformer and switching station and is stepped up to 110,000 volts.

In the control of the plant arrangements have been made for automatic synchronizing of the machines. Normally, the machines will be synchronized by the operator, but in case of trouble, when the operator's attention may be directed to other features of the plant's operation, a small switch on the board can be

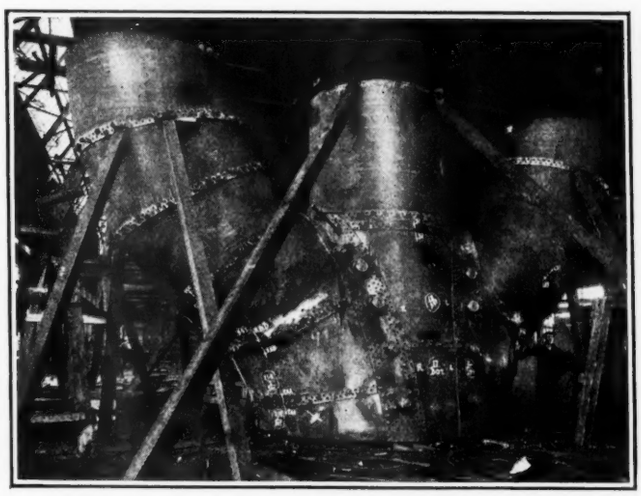


Fig. 8—Manifold used between 14 ft. tunnel and 9-ft. penstocks

closed and the machines will come on the line automatically when conditions on the system are correct.

The generators are protected with differential relays which open when trouble occurs in the machines. When these relays open, the generator, transformer and field switches open and the emergency stop functions and shuts the machine down.

Provisions have been made for obtaining a record of the water by taking the drop across the penstock valves at the entrance to the turbine casing.

The engineering and construction work for the project was done under the supervision of the Power Construction Co., a subsidiary of the New England Power Co. The J. G. White Engineering Corp. acted as consulting engineers.

Boiler Furnace Design*

Air-Heater Tests Results in Europe and America—Furnace-Wall Construction—More Effective Gas Mixing Needed with Underfeed Stokers

BY EDWIN B. RICKETTS†

IF THE problem of the furnace designer were simply to produce a furnace having the highest possible efficiency, he would not be confronted with a very difficult task because it would be hard to surpass the work of that unknown Chinese engineer who used his fire to cook his dinner and afterward passed the products of combustion through brick flues in his bed, thus antedating Henry Ford by some 3,000 years in burning his fuel twice. If our problem were simply to produce high capacity, again we have ample precedent among the ancients, for the Book of Daniel describes a furnace built for King Nebuchadnezzar, which was operated for a considerable period at 700 per cent rating. The efficiency of this furnace was low, and according to the record it was rather hard on the firemen, but it suited the King and nobody else mattered.

Our problem is, therefore, not primarily to design a furnace that will have high efficiency; nor can we rest content when we have produced a furnace that combines high efficiency with high capacity, but our problem is to so design our furnaces that, when operated in conjunction with the other apparatus in the plant, we will be enabled, while maintaining the desired continuity of service, to produce the largest number of salable kilowatt-hours for a dollar, when fixed and operating charges are considered.

With regard to coal-burning equipment, the best test records to date show that, given conditions favorable to the type of apparatus used, there is little if any difference in the efficiency or capacity obtainable when using powdered coal or stokers.

The efforts of manufacturers during the last year have been largely devoted to the production of apparatus capable of higher sustained ratings than have heretofore been considered practicable. While some of these so-called super coal burners are still suffering from the pains incident to too rapid growth, their performance on the whole has been satisfactory. A number of installations, both of stokers and powdered coal, have been operated for considerable periods at ratings of 400 to 500 per cent.

The modern boiler furnace occupying all the space under the boiler, together with the almost universal demand for the highest obtainable efficiency, has presented a number of new problems to the furnace designer, which may now be considered.

THE VALUE OF AIR HEATERS

While the possibilities of increased boiler efficiency through the use of preheated air for combustion have long been realized by American engineers, the economies obtainable by the use of air preheaters did not appear particularly attractive until the rise in coal prices had greatly increased the value in dollars of our chimney losses. The apparent attractiveness of the air heater has been further increased in stations where multi-stage bleeding has been adopted for heating feed water because in such stations economizers are seriously limited in the quantity of heat they can absorb from the flue gases.

The accompanying table gives the test results of a number of air heaters that have been recently installed in this country and in Europe, indicating some of the economic possibilities of this apparatus.

In analyzing these test results, we should keep in mind the fact that this apparatus is new to the operators and may not have been tested under the most favorable conditions; on the other hand, the heaters were all new and serious operating and maintenance troubles may develop later. We should, consequently, regard this test data as preliminary only, withholding final judgment until more complete returns are available.

*Paper presented before the Metropolitan Section of A.S.M.E., New York City.

†Assistant to Chief Operating Engineer, New York Edison Co.

SUMMARY OF AIR HEATER DATA
(Figures given are averages of tests)

	United States				Foreign		
Location	Colfax Sta. Duquesne Light Co.,	Boiler No. 12 Calumet Sta. Commonwealth Edison Co.	Boiler No. 16 Calumet Sta.	Boiler No. 15 Northeast Sta. Kansas City Light & Power Co.,	England	Riorges, France. Benoist & Co.,	The Hague, Holland Hague Municipal Power Plant
Manufacturer	Combustion Eng'g Co.,	Combustion Eng'g Co.,	Babcock & Wilcox Co.,	Combustion Eng'g Co.,	Jas. Howden & Co., Howden-Ljungstrom.	Maison Emile Prat-Daniel.	Maison Emile Prat-Daniel.
Type	"Plate"	"Plate"	"Tube"	"Plate"		"Thermix"	"Thermix"
Boiler surface, sq.ft.	22,914	15,089	15,089	12,743	900	1,960	6,725
Superheater surface, sq.ft.	2,999	4,052	4,052	5,743			
Economizer surface, sq.ft.		9,700	9,700	8,100			5,130
Air-heater surface, sq.ft.	11,200	9,000	8,554	9,600		1,506	7,525
Temp. of gas, deg. F., air-heater inlet	482	335.8	291.4	295	583	500	392
Temp. of gas, deg. F., air-heater outlet	303	269.8	220.4	224	232		316.4
Temp. of air, deg. F., air-heater inlet	108	71.3	65.3	75		62.6	78.8
Temp. of air, deg. F., air-heater outlet	229	164.3	155.1	142	436	163.4	167
Weight of gas through air heater, lb. per hour	171,067	175,600					
Gain in efficiency due to heat absorption, per cent	2.8	1.66	1.72	1.98	8.6	2.7	2.2
Gain in efficiency due to better combustion, per cent	3.14			1.2	13.4	10.3	4.3

In addition to a number of heaters of the type just described, the following air heaters are being installed:

International Paper Co.—6 Ljungstrom rotary heaters for 450 deg. air temperature.

New York Edison Co.—1 Prat plate type heater for 400 deg. air temperature.

Commonwealth Edison Co.—1 Fin tube type heater.

Consumers Power Co.—1 Fin tube type heater.

Test data will probably be available on all these heaters during the coming year.

In view of the widespread interest in air heaters at the present time it may be well to review briefly some of the reasons for and against the use of this apparatus in central stations. The air heater affords a means of returning to the cycle a considerable quantity of low-level heat that would otherwise be largely wasted. Consequently, the use of this apparatus should be carefully considered in the design of central stations. Generally speaking, that central station will be thermally most efficient which heats the feed water to approximately the temperature of the water in the boiler and at the same time preheats the air for combustion either by means of bled steam or flue gases to a temperature approaching that at which the flue gases leave the boiler, and the maximum return of low-level

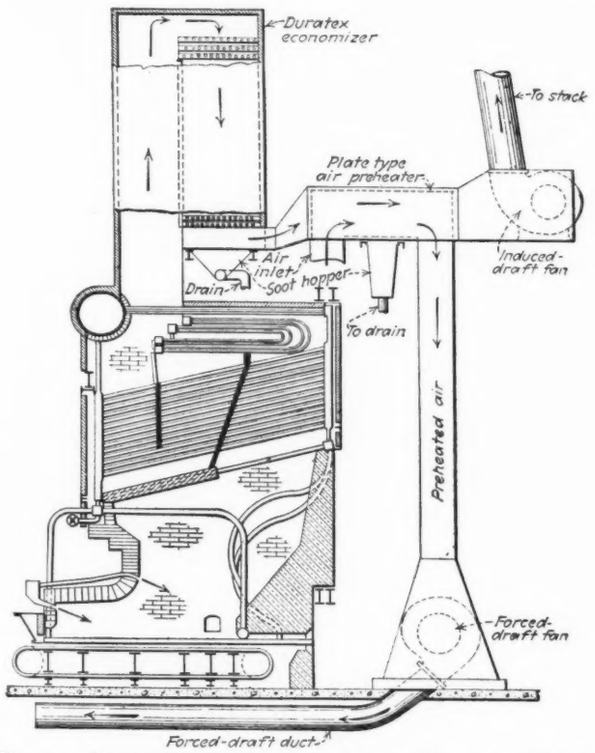


Fig. 1—General arrangement, boiler No. 12, Calumet Station of Commonwealth Edison Co.

heat can be obtained only when both feed water and air are heated to a relatively high temperature.

The air heater has been used in Europe for many years, but a careful review of technical literature, together with talks with European and American engineers who have studied the situation abroad, reveals the fact that there is little definite information available on the actual economic performance of air heaters in Europe. This lack of information is due to the fact that air heaters have only recently been applied to large central stations. Most of the installations so far have been of such a size relative to the boiler as not to preheat the air to a temperature above 250 deg. These heaters have been installed either following an economizer or in such a way as to absorb only a small part of the flue-gas heat. Consequently, very few operating data are available on the effect of high temperature on stoker and refractory maintenance.

The information at hand indicates that air heated to not over 250 deg. will usually cause no serious trouble

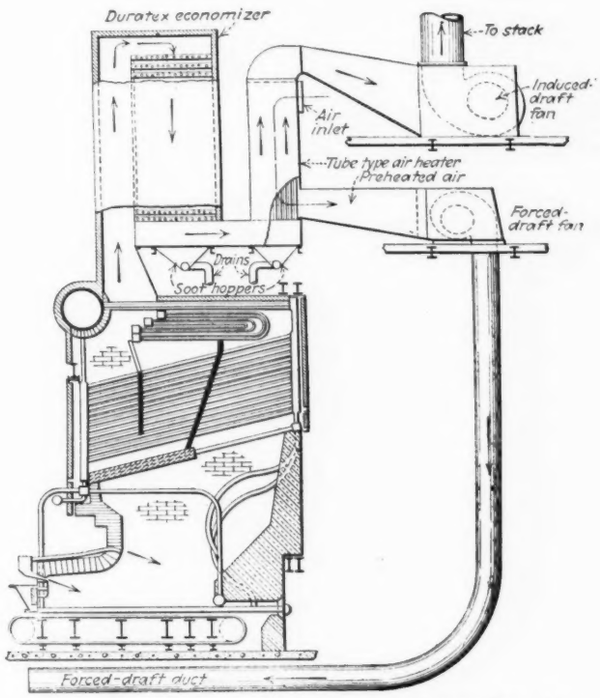


Fig. 2—Same as Fig. 1, but for boiler No. 16

with either stokers or brickwork. A few installations have been made where the air was heated to from 400 to 500 deg. F. One of these was an experimental installation in France on which some extensive tests were made by Monsieur Bosack, of the French Babcock & Wilcox Co. In this installation the air was heated to about 450 deg., and it was found that when using a coal having ash of a high fusing temperature no serious difficulties were experienced, but when ordinary low-fusing-ash coal was used, the clinker troubles were greatly multiplied.

At the North Tees Power Station in England air heaters have been installed for preheating the air to about 300 deg. Serious difficulties have been reported with both brickwork and stokers in this installation. The information available is not definite as to the part played by preheated air in the troubles at this plant.

The only installation in this country using highly preheated air is one of "type *E*" stokers under oil stills in the Chicago District and burning Illinois coal with air at a temperature of about 500 deg. In this installation serious clinker troubles have been experienced whenever high ratings have been attempted.

The indications are that heated air has in many cases advantages other than the straight return of a certain number of B.t.u. to the cycle. Those advantages are the more rapid combustion of the fuel usually accompanied by a reduction in excess air, in the carbon rejected with the ash, and the length of the flame. The

beneficial effect of heated air will probably prove more pronounced with those relatively low-grade fuels, high in moisture and ash, which in many cases will not produce a furnace temperature sufficiently high to make clinker troubles even with highly preheated air.

An air heater having a surface infinitely large would in very few cases be able to absorb in excess of 80 per cent of the heat in the flue gases, because in most cases 20 per cent of the weight of gases passing up the stack is accounted for by infiltration above the grates and through the flue connections.

It is hoped that the information that will be obtained on installations now being made in this country during the coming year will make possible a much more definite

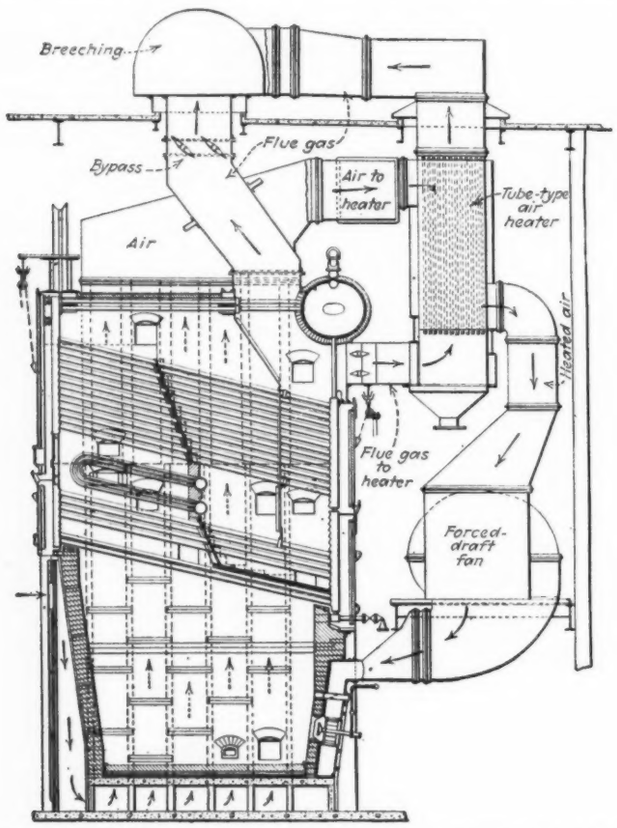


Fig. 3—Oil-fired boiler (20,000 sq.ft.) with air-cooled setting and air preheater, Houston Lighting & Power Co.

appraisal of the value of heating combustion air than can be done at the present time. Large-scale installations of air heaters will hardly be advisable until the advantages of this apparatus have been definitely established under the conditions of fuel, stoker, furnace, etc., which obtain in the plants under consideration.

Materials for Furnace Wall Construction

In his effort to produce a furnace for high capacity and efficiency, the designer is handicapped by the characteristics of the refractories commercially available. There is little difficulty in selecting refractories that will not fail by fusion under the ordinary conditions of boiler operation, but so far no firebrick has been demonstrated that will resist the slag action of all kinds of coal at high temperatures. On account of the wide variations in ash composition of various coals the prospects of an early solution of this problem are not bright. Rumors come to us from time to time that a universal super-refractory is about to become available which will solve all our problems, but so far these claims have not been demonstrated, and if we wish to get a furnace that will last under modern operating conditions, it will frequently be necessary to protect the furnace lining from the full effects of temperature and slag erosion.

The Mixing of Boiler-Furnace Cases

The development of stokers extending across the full length of the boiler has greatly accentuated the tendency to stratified flow of furnace gases. The gases rich in hydrocarbons and deficient in oxygen, which rise from the front of a stoker, have but little tendency to mix with the stream of gas containing large amounts of excess air coming from the thinner part of the fuel bed at the rear. These two streams mix after a fashion in the tube bank, producing secondary combustion with its accompanying high exit-gas temperatures. In some cases this mixing does not take place until after the gases have been cooled below the ignition point, causing losses due to CO and unconsumed hydrocarbons.

Practically nothing has been done so far in the matter of mixing gases on underfeed stokers, and the need for mixing is almost as great as it is with chain grate. It is generally felt by engineers operating underfeed stokers that the application of arches to this type of stoker is highly undesirable on account of maintenance costs. There is, therefore, an open field for inventive genius in providing a furnace design that will adequately mix the gases from this type of stoker.

Opportunities for Improvement

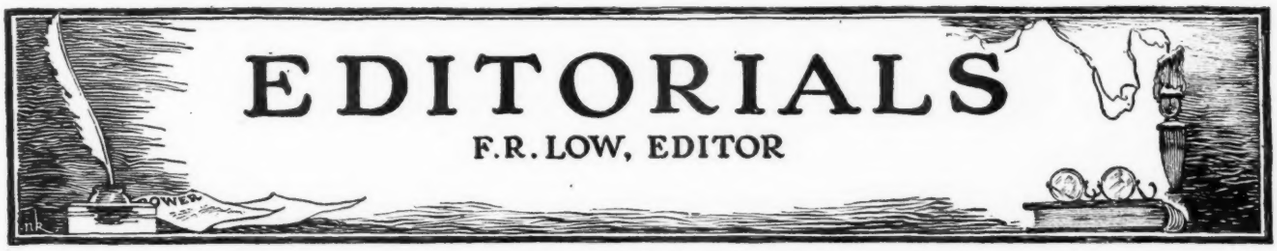
To my mind there is no field today in the combustion game in which the possibilities of improvement in efficiency are so large as they are in the proper mixing of furnace gases. Many of us have thought that the solution lay in high furnaces, but after an examination of a number of modern furnaces fired by both stokers and powdered coal, in which the tube bank was set twenty feet or more above the floor of the furnace, and having seen the flames carrying to the top of the first pass, I have come to the conclusion that it will not be practicable to build a furnace high enough to produce complete combustion before the tubes are reached unless some means are provided for bringing the rich and lean gas streams together.

Where the ratings are moderate, say not over 250 per cent, with modern setting heights, poor mixing will usually make itself felt only through higher flue temperatures but with the higher ratings that present-day practice demands, frequently losses of relatively large magnitude are realized due to carbon monoxide and hydrocarbons passing unburned up the stack.

Heated combustion air will undoubtedly help to shorten the flame length, but I am loath to believe the claims of 15 per cent or more saving made by some of the European air-heater enthusiasts.

We are passing now through a period when ideas on furnace design are changing rapidly; many new schemes are being tried, but on most of them the experience has not been sufficient for their value to be definitely stated.

In the twenty-odd years that I have followed the operation and design of boiler furnaces, there has never been a time when I was less confident of my ability to design a boiler furnace than I am today.



A Small River Develops Large Power Output

ONE of the best examples of utilizing the potential power of a river in this country is that which is taking place on the Deerfield in Vermont and Massachusetts. This is particularly significant, since around many of New England's water powers industrial centers have grown up in such a way as to make it impossible to develop these sites in an efficient manner. The Deerfield River, being for a large part in a section of the country not suitable for industrial development, has been left so that modern power-generating methods may be applied in its utilization. Although the river is not much more than a good-sized brook during normal flow, by the use of storage reservoirs it is being converted into one of the country's important sources of water power. What has been done on this river, however, cannot be taken as a criterion of what can be done on others in general. Although there are no abrupt drops in the river, it has a comparatively steep gradient throughout its eighty miles of length, making it possible to use nearly the whole two thousand feet fall for power development at reasonable costs. For about fifty per cent of its length at the upper end it flows between steep banks in a country that is sparsely populated, which makes this section suitable for storage reservoirs to regulate the run-off in such a way as to give practically a constant flow. Another feature is that materials are readily available for constructing earth dams such as have been used for forming the reservoirs.

Even with favorable conditions these developments are by no means simple problems. In the Davis Bridge project, which is described in this issue on page 776, is involved the highest earth dam ever constructed, the relocation of eight miles of railroad, building of new highways, flooding twenty-two hundred acres of farm and wood land and the construction of a new type of spillway to care for a possible flood of thirty thousand second-feet, all of which was necessary to make possible the erection of a sixty thousand horsepower station, the largest development on the river. This station is connected to the reservoir through a fourteen-foot tunnel, two and one-half miles long.

In creating a storage reservoir, the chief factors that enter into the economy of the problem are the cost of the development and the head that the water can be used under. If the cost of the reservoir is high and the head low, then the project may be impossible economically. On the other hand, with reasonable construction costs and a high head in the river below the reservoir, the possibilities for an economical development are favorable. The latter is the case on the Deerfield, where the heads are such that when the river is completely developed each cubic foot of stored water will produce between one hundred and two hundred horsepower.

Conditions involved in the development of water powers are just as varied as the sites on which the developments are made. What is done in one locality does not apply to another; each must be tested by the laws of economics. However, the Deerfield River is a good example of how a small river can be converted into a source of large power output when conditions are favorable for the intelligent application of modern engineering.

Another Huge Station In the Metropolis

THE spectactular features of Manhattan's development have blinded many to the fact that her sister borough, Brooklyn, is one of the world's greatest manufacturing centers and has a population considerably larger than that of Philadelphia. In fact experts predict that Brooklyn's population will soon exceed that of Manhattan.

About two years ago all doubt as to the general trend of Brooklyn's load curve having been removed, the Brooklyn Edison Company laid out a bold scheme of expansion involving the erection of a huge power station, the first section of which was to be installed without delay. As a result we see today the completed structure for the first half of the 400,000-kilowatt Hudson Avenue station, with one 100,000-kilowatt generating group about ready to start operation and an additional 50,000 kilowatts on order.

Hudson Avenue is spectacular in a number of respects. Its 50,000-kilowatt units are the largest ever mounted on a single shaft. Its 70,000 square foot condensers are the largest ever built. Its foundation, consisting of a ten-feet thick reinforced-concrete mat resting on piles sunk into sand and quicksand, is perhaps unique in large station construction.

Being necessarily situated in the heart of a congested metropolitan district, the Hudson Avenue station cannot properly be compared with those in less densely populated areas. In Greater New York the best plant for purposes of local comparison, because the largest and most recently constructed, is doubtless the Hell Gate station. The two are similar in a number of ways. Both are laid out on the group system, with two main generating units and one house turbine per group. Both use water-tube cross-drum boilers. Both handle coal with grab buckets, coal towers and overhead track systems and both remove the ashes by hydraulic sluicing. Finally, the steam conditions—for the present at least—are practically the same. It is a reasonable assumption that all these features have worked out well at Hell Gate, else they would not have been incorporated in the design of the Hudson Avenue station. The steam conditions (265 pounds and 611 degrees at the throttle) seem rather conservative for a new large station, but in this connection

consideration must be given to the extraordinary importance of reliable service in the metropolitan district. It was thought essential to eliminate any untried elements that might introduce the possibility of shutdowns.

Certain resemblances between the two stations have been pointed out. The differences are just as striking. The generating units, while of the same general types as those used at Hell Gate, are considerably larger—50,000-kilowatts instead of 35,000 and 40,000 kilowatts, as in the original Hell Gate installation. These, although the largest single-shaft units ever built, were felt to possess the necessary dependability. It is evident that the selection of the largest available single-shaft units insured the greatest capacity for a site of limited area. This was an important consideration, because very few suitable locations were available, and these were limited in size. The impossibility of choosing any desired site made it necessary to erect this plant on a layer of sand, beneath which was quicksand. Extraordinary difficulties were encountered and overcome in the design and erection of the foundations. The nature of the subsoil led to the placing of the turbine room inshore, where its heavier and more delicate machinery would have a firmer footing. At Hell Gate different conditions led to a different arrangement. There a good rock foundation was available, so the turbine room was placed next to the river, thus saving a huge sum in circulator tunnel excavation.

At Hell Gate each 75,000-kilowatt group receives steam from six boilers, while at Hudson Avenue eight boilers furnish steam for each 100,000-kilowatt group. As a result the boilers are of about the same size in the two plants. While by no means small, they are not as large as some that have been erected in large stations during the last two or three years. The adoption of this particular size of boiler in the present installation is probably based to a considerable extent upon the desire to insure full operating capacity at all times without providing a great excess of installed boiler capacity. Allowing for the possibility of one boiler per group being laid off for cleaning or repairs, it is evident that with four boilers per group 33⅓ per cent excess capacity would be required, while with eight boilers the additional capacity would be only 14.3 per cent. Furthermore, if it should become necessary to take two boilers of one group off the line at the same time, it is clear that a group with eight boilers could carry a much higher load than could one with four boilers.

By heating the feed water first with the exhaust of the house turbine operating under a fair vacuum and then with steam bled from two stages, Hudson Avenue approaches more closely than Hell Gate to the theoretical regenerative cycle without any sacrifice of reliability. Finally, it is of particular interest to note the provision that has been made for the installation of centralized combustion control, a new development that promises much in decreasing the gap between test efficiencies and those obtained in daily operation.

While the air heater is forcing its way to the front in this country, the economizer seems also to have obtained a new lease of life, due largely to the development of simple schemes for preventing corrosion. Neither of these devices is at present installed in Hudson Avenue, but engineers will watch this station for further developments along this line.

Shutting Down Steam-Turbine Units

THE operations of shutting down a prime mover usually receive less consideration than those of starting up. The latter is an exacting process, and carelessness or mistakes are likely to bring on immediate consequences, such as vibration, overspeeding or condenser trouble. Ill-advised moves in taking a turbine out of service, on the other hand, seldom produce as startling results. Blade erosion or generator trouble may be caused in an accumulative manner, which is slower to develop and not so easily traced back to the source.

Blade erosion, although not comparatively serious in extent with modern materials, can in many cases be minimized by proper care. A leaky throttle valve tends to project steam against the first blade row. Erosion may be produced in high-pressure stages in all types of turbines from this cause. Therefore, when standing idle for ten hours or more, the main header valve should be closed and the pipe connection between the steam header and the throttle drained. Steam pressure is thus removed from the throttle valve. An atmospheric vent is preferred to one leading into a sump where several pounds back pressure exists, which also applies to other turbine drains.

When shut down for several months, the blading can be advantageously protected by introducing oil into the casing while the unit rotates at low speed. The internal mechanism will thus be effectively sluiced. As a further precaution the steam and drain piping could be disconnected and blanked off at each side.

Water is normally present in the low-pressure stages of a condensing machine. The vanes may be dried off in the low-pressure stages by drawing a small quantity of air through the turbine with the vacuum pump for several hours after shutting down.

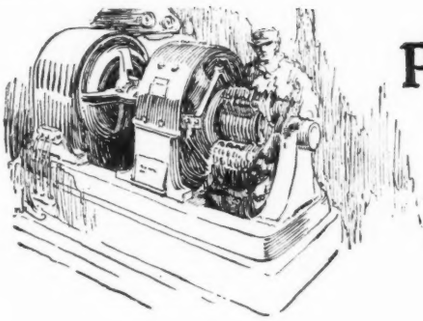
A tendency of the emergency valve to stick or become sluggish after an operating period, may be checked by using the hand trip each time the unit is taken off the line.

Temperature changes in a turbine receive, necessarily, a large amount of attention both in design and operation. Temperature changes in the generator, however, are less important and in operation are seldom considered in the light of causing trouble. It is known that cold windings, subjected to warm air currents, tend to condense moisture. When standing over night, the generator may become cooler in some instances than the air it would receive if started up in the daytime. Investigations reveal that corona is frequently thus caused in high-voltage machines, leading to deterioration of the insulation. It has been suggested that means be employed for keeping generators warm enough when idle, to avoid condensation in starting up.

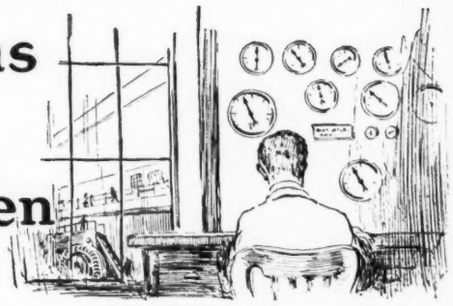
A glaring sample of the misinformation that is being persistently disseminated about Muscle Shoals is the following:

Officials of the Alabama Power Company which, as the leader in a group of Southern power companies, made the Government an offer of approximately $105,000,000 for Muscle Shoals as the center of a super-power zone have had little to say about the Ford offer. . . . The Ford bid involves the payment of about five million dollars.

If there were any offer that was 21 times as good as another, the solution of the problem would be easy.

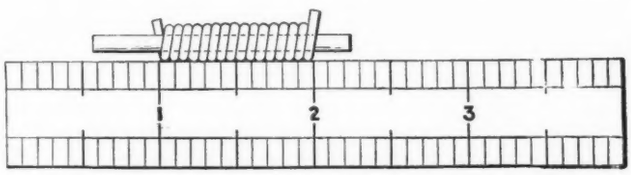


Practical Ideas *from* Practical Men



Measuring Diameter of Wire with Ordinary Rule

Frequently, when the diameter of small wire is wanted, no wire gage or micrometer calipers are handy with which to make the measurement. Under such conditions the diameter can be readily determined by coiling the wire around a small arbor, pipe, large wire nail, or similar object, counting the number of turns



How rule is used in determining diameter of wire

in one inch of length and then dividing one by the number of turns to obtain the diameter in hundredths of an inch. If care is taken to keep the coil tightly wound, without space between the adjacent turns, a fair degree of accuracy will be obtained. H. M. NICHOLS.

Readville, Mass.

From 22 Per Cent Operating Loss to 7 Per Cent Profit

For six years after it had been put into operation, the small electric light and power plant of the town of Tonkawa, Oklahoma, was operated at an annual loss amounting to approximately 22 per cent on the investment. Then a new manager was put in charge, and within one year the plant was earning 7 per cent on the investment, exclusive of taxes.

The generating equipment consisted of one 50-kw. and one 75-kw. three-phase 2,300-volt generator, directly connected to high-speed steam engines. Natural gas with a calorific value of 900 B.t.u. was used for fuel at a cost of 13c. per thousand feet.

The first intimation that something was wrong came with the discovery that the gas was running 534 cu.ft. per kw.-hr. Upon investigation the boiler efficiency was found to be only 39 per cent. This efficiency was increased some by cleaning out the combustion chamber, which had been filled up to within about 12 in. of the bottom of the boiler, and by stopping air leaks in the furnaces and steam and water leaks in the boilers. These changes brought the boiler efficiency up to around 69.5 per cent. The engines were then indicated and found to run around 50 per cent efficiency. After expending about $270 for new cutoff valves, the efficiency was increased to around 80 per cent. These improvements to the boiler and engines reduced the fuel bill approximately $250 a month on the same load.

The next thing done was to see what improvement could be made in the service, as it was far from satisfactory. About 10 o'clock each night, when the load dropped to a certain point, the service transformers that connected the two units in parallel would buck one another and cause a bad fluctuation in the lights. This was overcome by cutting the transformers out of parallel and operating them independently. After making these changes or improvements, we were ready to make a drive for a dividend.

The following figures were compiled from tests we conducted before making the changes just mentioned. The current was sold on a flat rate of one-half cent per watt of connected load except on 42 services which were metered and which averaged about $1.50 a month, or $756 a year. There were 102 customers not metered, and to those the current was supplied at ½ cent flat rate; that is, a 100-watt lamp brought 50 cents a month and all other lamps in proportion. The income from these services averaged $383.20 monthly, or $4,586.40 a year, and this plus $756 for the metered service gave a yearly income of $5,342.40. The yearly output amounted to approximately 72,000 kw.-hr.

The plant and distribution circuits cost a total of $30,000, the plant alone costing $10,550 and the distribution circuits $19,450. The total fixed charges, exclusive of taxes, on the power plant amounted to $1,369.40 and on the distribution system $2,083.55, making a total of $3,452.95, or $0.0479 per kw.-hr.

The total operating expenses, including salaries, fuel, water, oil, etc., before the changes were made amounted to $8,747, or $0.121 per kw.-hr.; of this amount $4,996.80 was for fuel alone. Then the operating expenses plus the fixed charges of $3,452.95 brought the cost of producing energy up to a total of $12,199.95, or 16.9 cents per kw.-hr. which, when the income of $5,342.40 from plant operation was deducted, left an annual loss of $6,857.55 or approximately 22.5 per cent on the investment. This was the operating condition at the Tonkawa Electric Power Plant before the improvements were made.

After everything was adjusted, and we had our load built up to 10,283 kw.-hr. average per month, or 123,400 kw.-hr. a year, we set a rate of 10c. per kw.-hr. and put meters on every service.

At the end of the first year after these changes had been made, the output had increased from 73,000 to 123,400 kw.-hr. and the operating expense had been reduced from $8,747 to $6,629.90, which reduced the cost per kilowatt-hour from 16.89 to 8.17 cents. The income from the plant operation now amounted to 123,400 × 10 = $12,340, and total cost of producing the current amounted to $6,629.90 + $3,452.95 =

$10,082.85, leaving a profit on the year's operations of $2,257.15, or 7.6 per cent on the investment.

During the process of improving the plant, the gas consumption was reduced from 534 to about 175 cu.ft. per kw.-hr. Even 175 cu.ft. was too high, but this was due to the low efficiency of one of the generators, which was less than 60 per cent.

Some years later we found that even a greater saving could be made by shutting down the station and purchasing power from a near-by city, our generating cost at that time being about 8.2 cents a kilowatt-hour.

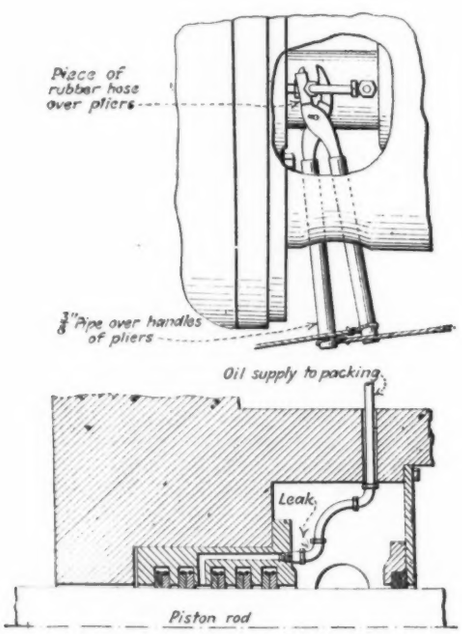
By purchasing our current and guaranteeing a consumption of 12,000 kw.-hr. a month, we got our electricity for 6.25 cents a kw.-hr. This contract, which is still in force, runs for a ten-year period.

Ponca City, Okla. V. K. STANLEY.

Stopping the Steam Leak with the Engine in Service

One Monday morning recently a leak developed in an elbow on the oil pipe leading to the stuffing box on one of our engines. It not only created a disagreeable noise owing to the steam blowing out, but prevented any oil being supplied to the packing. As we did not wish to shut the engine down to put on a new ell and it was imperative that the packing be kept lubricated, we used the method shown in the illustration to stop the leak without taking the engine out of service.

A small pair of pliers were obtained and a piece of rubber hose was placed over one jaw and a piece of



How pliers were used to stop the leak

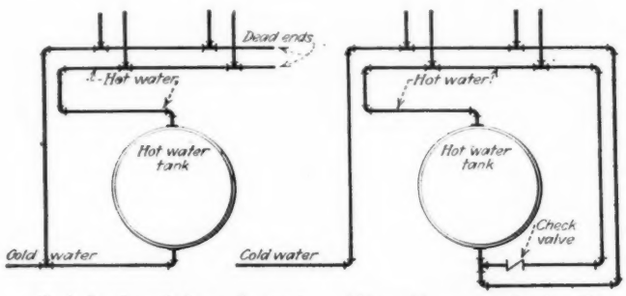
⅜-in. pipe put over each handle. Then the pliers were inserted through the opening in the side of the engine frame and the rubber hose pressed over the leak and the ends of the pipes tied in opposite directions on the engine frame. This stopped the leak entirely and the engine was kept in service all the week, and the following Sunday a new ell was put in. A. A. FETTE.

New Iberia, La.

How Water Consumption Was Reduced and the Service Improved

After our institution received a water bill that seemed extraordinarily large, I was called to the office and requested to make a careful inspection of the water system in the building and to determine if possible the cause for the large consumption. Accordingly, an inspection was made but no leaks were found.

I then directed my attention to observing how the water was used in the different services in the building,



Original piping layout and tank connections *Alterations made in the piping arrangement*

and this soon revealed the cause of the trouble. When a drink was needed, several gallons of water was wasted in running off the warm water in the pipe in order to get a cold drink. On checking up, I found that anywhere from 1 to 10 gal. was wasted in order to get a cold drink, the amounts varying at different locations of the faucets.

After some consideration the following changes were made in the piping layout, which proved to be successful and considerably reduced the water consumption. Fig. 1 shows the original piping layout and Fig. 2 the changes made in the piping arrangement.

A large amount of water around 130 deg. temperature was required for kitchen and laundry service, and with this in view we connected the dead end of the cold-water line to the feed inlet of the hot-water tank and disconnected the original cold-water line, as shown in Fig. 2. Then, when hot water was drawn from the tank, it was replaced by water that had passed through the cold-water pipes of the building instead of coming direct from the main to the tank. In this new arrangement of piping the water at the faucets was much cooler, and at many of the faucets it was at all times cold enough for drinking. This not only reduced the water consumption, but the temperature of the water entering the tank was increased from 10 to 15 deg. by passing through the warm building. The cold water entered the building at about 45 deg. F., and the heat added to it by passing through the building amounted to about 15 per cent of the total heat required to raise it to the necessary temperature.

Further savings were made by connecting the dead end of the hot-water line to the feed inlet of the tank, as shown in Fig. 2. This gave a constant circulation and thus maintained a supply of hot water at each faucet. In order to prevent cold water feeding back through the hot-water line, a check valve was installed in the line near the tank as shown. The decrease in the water consumption and the improvement in the service soon paid for the changes made to the piping.

Winnipeg, Man., Canada. C. RYE.

Comments from Readers

Where Should the Water Be Discharged in a Return-Tubular Boiler?

Answering R. E. Graves' question in the Jan. 29 issue, I would say that the two most objectionable places in a boiler of the return-tubular type, for scale deposits, are the bottom of the shell and the rear tube sheet. To prevent deposits on the shell bottom, the feed pipe should not discharge below the tubes. To prevent deposits on the rear tube sheet, the feed pipe should not discharge near the rear end if the circulation of the water is toward the rear above the tubes.

In a battery of boilers with which I am familiar the feed pipes were at one time arranged in different ways. In some cases the pipe was carried down between the middle rows of tubes to the bottom. As only raw water was used and most of the time it was cold and at no time above 145 deg. F., the shell was in bad condition. The plates were fire-checked at the girth seams, the checks extending in many cases completely through to the rivet holes. They were all eliminated finally, by repeated electric welding. Many of the rivets also had to be renewed. In some of the boilers there was a pan into which the feed pipe discharged. Later pans were made for all the boilers, and as the circulation of the water is from the rear of the boiler to the front above the tubes, the rear tube sheets are now in good condition and the girth seams tight.

In my opinion any pan that can be passed through the manhole is too small to serve as a trap for scale-forming material. Its chief purpose is to form a seal for the end of the feed pipe. It will also reduce the velocity of the water, but that is of little advantage. Another reason why it cannot catch any scale-forming material is that the temperature of the water will not be high enough to precipitate the impurities while it is in the pan.

Undoubtedly, a nest of pans, arranged one above the other as in some types of heaters, would give excellent results, but the objection to that arrangement would be the space the pans would occupy. R. McLAREN.

Toronto, Ont.

Indexing and Filing Articles

I was much interested in the article by H. B. Hodgins in the Feb. 26 issue on the subject of "Indexing and Filing Articles," which made special reference to an article on the same subject published in the Jan. 15 issue. The latter article advocated the clipping of magazine articles and the filing for future reference, while Mr. Hodgins advanced the opinion that it was better to retain each issue complete after stripping it of the advertising pages, and that each volume, together with the volume index should be fastened together and preserved. Gordon J. White also contributed to the discussion in the April 1 issue. I heartily agree with Mr. Hodgins and Mr. White. The engineering and other professional magazines of this country are well worth preserving in a bound state, even if the binding is a cheap one.

The main arguments for the clipping system are the following: (a) The space required for filing is reduced to a minimum; (b) articles upon the same subject are grouped together; (c) the shortest possible time is required for locating a desired article or collection of articles; (d) only such articles as are really of reference value are filed, and the time consumed in looking up from a general index, articles that prove to have little or no bearing on the subject desired, is saved.

It has always seemed to me that if a magazine was clipped and only articles of immediate and personal interest preserved, valuable material for future reference might be thrown away. One's personal interests and special lines of work a few years hence may change materially, and articles that might be discarded today may be of great value for reference a few years later. This has been my experience during more than twenty years of active engineering practice.

In order that the information contained in bound volumes of all engineering magazines may be readily accessible and that such a file shall have the same advantages as cited under (b), (c) and (d) for the clipping file, something more is necessary than the regular volume index, as for instance a card index. This point is also brought out by Mr. White. To the busy engineer, however, the making and the keeping up of a card index must involve very little work or it cannot be attempted. I have found that the scheme that I am now using requires even less time than the clipping and filing system. The engineering magazines of the present time include in each issue a fairly good index of the articles of that particular number. Some of these not only give the title and page number, but some information as to the length of the article and whether it is illustrated or not, and some even a short synopsis of the article. It is a simple matter to clip this index page and paste the slips, referring to articles that one desires to index, on standard index cards. If the article is especially good or if it brings out something of special value, a note to that effect can be written below the clipping and a complete index card is obtained with a minimum of effort. Further classification can be provided by the arrangement of the cards in the file.

It seems to be the universal opinion that topical rather than alphabetical indexing is better suited to the engineering office. It is in this particular that the regular volume index is deficient; any article or subject can be found, but time and patience are required. The card index should be divided into (1) sections, (2) divisions, (3) subdivisions, (4) topics, (5) subtopics.

The "Section" divisions are the separation into the different branches of engineering such as civil, mechanical, electrical, etc., if one is interested in more than one branch. Each section can be given a separate drawer or file box or the sections divided by stiff cardboard separators. The divisions of each section are

separated by full tab cards, the subdivisions by one-half tab cards and the further classification into topics by one-quarter tab cards. On each index card, in the upper left-hand corner, is written the topic under which the article is filed and in the upper right-hand corner the subtopic. This allows a card to be easily and quickly returned to its proper place.

Such a general scheme allows anyone to arrange an index in a manner best suited to his needs, to any degree of classification desired, and with the possibility of extending at any time if necessary. For example, an article on the "Advantages of Cross-compound Impulse Steam Turbines" would be indexed as follows:

Section: Mechanical engineering.
Division: Heat engines.
Subdivision: Steam turbines.
Topic: Cross-compound turbines (on card).
Subtopic: Advantages: "

and an article on "Filter Plant Control of Chlorination by Excess Chlorine Method";

Section: Civil engineering.
Division: Water supply.
Subdivision: Sterilization.
Topic: Liquid chlorine.
Subtopic: Plant control excess chlorine method.

In the last few years librarians have given the subject of topical indexing much study. Reference is made to the University of Illinois Extension of Dewey and the Dewey decimal classification to engineering literature. The "Classification of an Engineering Library," published in the "Transactions of the American Society of Civil Engineers," Vol. 22, December, 1918, page 1618, is also a good basis upon which to arrange a topical index. I believe the satisfaction that will be experienced in having complete volumes of the engineering magazines, and at the same time a ready and quick way of locating any desired article on any particular subject, will be such as to repay one for the effort of trying out the plan outlined.

Norfolk, Va. C. L. B. ANDERSON.

Why the Blowoff Discharged Below the Water Level

Referring to the answer given to question 90 on page 486 of the March 25 issue, one sentence reads, "In no case should the blowoff discharge be below the water level in the cistern." This calls to mind an installation I came across some time ago while doing some erection work. A blowoff cistern about 3½ ft. in diameter and about 5 ft. high had been constructed with an opening for screwed pipe connections on each side of the shell and close to each head. When the cistern was installed and connected, the blowoff discharge entered the bottom and the top opening discharged to the sewer.

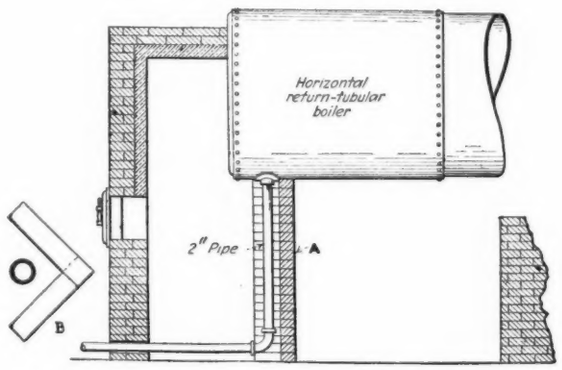
Upon inquiring as to the reason for connecting the tank in this manner, I was informed by the man in charge that they had been installing them that way right along and had never experienced any trouble. His explanation was that when the boiler was blown down the increased temperature and violent action of the incoming water would easily drive out the water and sludge left from the previous blowdown with the result that not enough mud and sediment would be left to interfere in any way with the incoming discharge of the next blowdown. R. E. KEECH.

East Akron, Ohio.

Blowoff-Pipe Failures

In the Feb. 12 issue Mr. Wakeman shows a layout of blowoff piping that has been in service for nearly thirty years. In commenting on this long period of service in the April 1 issue, Mr. McLaren says: "Thirty years is a long time for piping to last, and the obvious explanation is that the size of the pipe (4-in.) permitted a plentiful supply of water in the pipe at all times, thereby preventing overheating, whereas with the usual size (2-in.) there might have been a deficiency of water and overheating." The small size of pipe may be the cause of overheating in some instances, but it certainly does not apply to all cases.

In a battery of two 150-hp. horizontal-tubular boilers of which I have charge, the blowoff pipe is made of 2-in. pipe, and arranged as shown in the illustration. The



Arrangement of blowoff pipe and brick baffle

baffle is constructed as shown in the detail *B* on McLaren's drawing, and reproduced herewith. Although these blowoff pipes have been in service for twelve years, no failure has occurred, nor is there any sign of corrosion.

Stanton, Mich. F. L. PAKES.

The article by R. McLaren brings to mind some experiences I have had along this line, which may be of interest.

In the first place I notice he has used a right-and-left-hand coupling in connecting the pipe to the boiler. It is not good practice to use couplings on blowoff pipes at all, especially in the combustion chamber, but in such a case I think instead of putting the coupling in the vertical pipe it should have been placed in the horizontal pipe.

It is not unusual for pipefitters to put in old pipe on which the threads have become badly worn, and to depend on the last two or three turns with the wrench to make the joint tight. When this is done, practically all of the strain is thrown on one or two threads and these soon give way particularly if the boiler is shut down at night and started up each morning.

In my opinion it is good practice to so connect the blowoff valves or cocks that the expansion will be taken care of in the swivel action on the elbow or angle valves. Where pressures over 150 lb. are carried, extra-heavy fittings only, should be used and all short connections should be made with flanged fittings.

On one occasion, when taking charge of a plant, the fireman reported that the boilers had not been blown down for a long time. Upon investigation it was found

that the blowoff pipe, which was unprotected, had burnt off, but the vertical pipe was plugged so solid with scale that it held against the pressure.

On another occasion the repairman was told to cut a new piece of pipe to replace the vertical section of the blowoff on which the threads were worn, and to have it ready before he left at 5 o'clock, as the boiler must be in service that night. He was instructed to cut the thread large with an adjustable die, as the threads were worn in the reinforcement patch on the boiler. As he considered the time short in which to do the job, instead of preparing a new piece of pipe he put the old piece back, simply turning it end for end. He reported the job complete at 5 o'clock and the boiler was steamed up and cut into service. After it had been in operation about 36 hours, the elbow pulled off the end of the pipe and before the fireman could attempt to draw or cover the fire, the boiler was dry and considerable damage had been done to the plates.

In some boilers where arches are used in the combustion chamber, it is not convenient to put a brick pier in front of the pipe. In such a case I have used asbestos rope to wrap the blowoff pipe and found it very effective, but it had the disadvantage of expensive renewals each time after inspection.

The experiences cited in the foregoing should serve to drive home the fact that too much attention cannot be paid to the blowoff valves and connections.

Cambridge, Mass. R. A. CULTRA.

High Cost of Machinery

The editorial in the April issue would seem to infer that there should be some way for the manufacturer to do business without spending much money for sales or service. I doubt if this can be done in the majority of engineering problems.

Take an article as simple as an automobile. It should be possible for the buyer, by inquiry among his friends, to decide upon the type and merit of a particular car. According to the argument expressed in the editorial, he then should be able to send his order to the factory and cut out the high selling and service costs that he pays for under the present system.

If any automobile manufacturer could sell his automobiles in this way, he would be glad to be thus able to reduce his price and vastly increase his sales. There is no money of course in his pocket from sales or service; it is a handicap on his business as well as a handicap on the purchaser.

Fifteen years ago I founded a business based on the opposite theory. We do not believe that machinery is a foundry and shop product. We believe brains to be the most important factor. The brains necessary to design and improve apparatus, as well as the brains and man power necessary to sell and serve the customer, apparently cannot be removed from the article. Even so simple a thing as bread or milk needs a lot of other elements besides the flour and yeast or what might be called the shop process.

The question is an important one because cost elimination is vital and excessive cost hurts the manufacturer more than it hurts the buyer because his volume of sales depends upon his ability to reduce costs to or below competitive prices. He would be the first to grasp any sound method of eliminating advertising, sales or service expense. The money the customer gives him for these costs he turns over to these various departments. The automobile manufacturer does not feel comfortable when he views the difference between his price for an automobile and the price the customer pays. If these costs can be reduced or entirely eliminated, he will probably be the first to discover the method.

It seems to me that the whole question simmers down to how much iron and how much brains the customer buys. He usually views his purchases as so much per pound, but inasmuch as the product is iron plus brains, there does not seem to be any logical way yet discovered to reduce very much the cost of materials or the cost of brains except through large sales volume and quick turnover, which factors increase sales expense and brain factor in general.

Probably the best way to prove the cost is to attempt to buy an article that contains considerable weight but required little brains to design or manufacture. Practically every article we wear or eat or use is not bought on this basis. It includes the quantity of brain and labor that you must pay for, because the brain and labor man must live.

R. H. BEAUMONT, President,
Philadelphia, Pa. R. H. Beaumont Co.

[Apparently, the editorial was not so clear as it might have been. The thought was not that the manufacturer should charge only for the bare cost of manufacturing with no addition for the research and engineering development as well as the sales effort. It is a matter of common observation that there is a tremendous amount of duplication of engineering investigation of a particular proposition, and it was the editor's belief that this was outside the legitimate field of the manufacturer and covered matters more economically handled by the plant executive or by a consulting engineer.—Editor.]

Leaky Compressor Valves

In *Power*, April 15, appears an article on air compressors wherein the author, William V. Fitzgerald, falls into a very common error. He states that "the air, leaking past the valves, through the restricted openings, becomes excessively heated owing to the friction." This is so contrary to the facts that the statement should not be allowed to stand unchallenged.

Leaking past a valve is a throttling or nozzle action. The total amount of heat in the air before and after passing the valve remains constant, and the temperature will be lower after the valve has been passed.

The reason for the high temperature of a leaky valve is that the air leaking past the valve, although dropping in temperature, never reaches the compressor suction temperature. The addition of a quantity of the high-temperature air raises the initial air temperature, which, of course, causes the discharge temperature to be somewhat higher than before. The addition of a small amount of this air, leaking back into the cylinder, raises the temperature of the next suction charge still higher, resulting in a much greater discharge temperature. This action often continues until the valve becomes red hot. JOHN CASSIDAY.

Jersey City, N. J.

A CORRECTION—In the article on page 654 of the April 22 issue entitled "Burning Anthracite on Stokers," the title of the top curve on the chart showing results obtained, should have read "Per cent loss due to combustible in ashpit" instead of "per cent combustible in ash" as given.

QUESTIONS AND ANSWERS

Conducted by Franklin VanWinkle

Ratio of Cost of Steam Chargeable to Power

In figuring the cost of power generated by a non-condensing turbine where all the exhaust is used in manufacturing processes, how is the ratio of cost of steam to be estimated where credit is to be given for condensate returned from the processes? *V. R. C.*

Where the total cost of steam generated is represented by B.t.u. in steam generated minus B.t.u. in the condensate returned from the processes, the ratio of cost of steam used for development of power would be:

$$\frac{\text{B.t.u. in steam generated} - \text{B.t.u. in exhaust of turbine}}{\text{B.t.u. in steam generated} - \text{B.t.u. in returned condensate}}$$

Variation of Lead of Single-Valve Automatic Engine

How can the lead be increased or decreased on a single-valve automatic shaft-governor engine? *R. N. P.*

Lead depends on the angular advance of the eccentric with respect to the crank, and in most automatic shaft-governed engines the angular advance is not adjustable with respect to the governor wheel, which is keyed to the shaft. The lead of the eccentric is fixed by the builder of the engine, and the only variation of lead is by adjustment of the length of the valve stem or eccentric rod for equalizing or changing the relative lead of opposite ends of the valve.

Quality of Steam from Data Obtained with Separating Calorimeter

In using a separating calorimeter, the glass gage showed that during a certain time the calorimeter collected 0.24 lb. of water, and during the same time the weight of condensing water into which the dry steam was separately condensed had increased 4 lb., 9 oz. What was the quality of the steam? *S. M. E.*

As 9 oz. $= \frac{9}{16}$, or 0.5625 lb., the weight of dry steam that was condensed was 4.5625 lb.; and as the total weight of steam handled was $0.24 + 4.5625 = 4.8025$ lb., the quality, or percentage of dryness, of the steam was $4.5625 \div 4.8025 = 0.95$, or 95 per cent.

Removing Bagged Tube from Water-Tube Boiler

How can a bagged tube be cut off and removed from a straight-tube water-tube boiler? *W. L. C.*

The tube can be cut off on each side of the bag by an inside cutter operated from the end of the tube. The expanded ends may be split with a cape chisel and crushed for removing straight portions of the tubes, as commonly practiced in removal of tubes from fire-tube boilers, or an inside tube cutter can be used for cutting off a tube end near the header when the expanded end is more easily crushed and removed. When bagged or blistered portions of a tube have been cut off, the other sections of the tube end usually can be pulled through the tube hole with or without taking hold of the inside of the tube with an "expanding wedge" with eyebolt.

Buckling of Tube Sheets from Retubing

In retubing a horizontal return-tubular boiler, why is it necessary to leave some of the old tubes in place until some of the new tubes have been set? *W. M.G.*

A tube expander is likely to have greater effect on one side than the other of a tube sheet, and when the same tool is used on all tubes, the tube sheets are drawn together or pressed apart. To prevent buckling of the tube sheets when retubing, a few old tubes are left in place near the center of the tube sheet and about half way between the center and the shell for holding the tube sheets in place until other tubes have been replaced.

Pressure Overcome by Feed Pump

A boiler-feed pump is located 15 ft. below the water line of the boiler and takes water from a tank 8 ft. below the pump cylinder. If the pressure in the boiler is 80 lb. gage, neglecting friction losses, what is the total head in feet the pump must act against and the equivalent pressure in pounds per square inch? *A. F. D.*

A boiler pressure of 80 lb. gage at the surface of water in the boiler would be equivalent to a head of $2.3 \times 80 = 184$ ft. of water, and with a suction lift of 8 ft. and the pump 15 ft. below the level of water in the boiler, the total pressure for the pump to act against would be $8 + 15 + 184 = 207$ ft. head, or $207 \div 2.3 = 90$ lb. per square inch.

Water for Raw-Water Ice

Is there any way of treating water to remove sodium sulphate and sodium chloride to render the water suitable for making raw-water ice? *F. G. R.*

About the only way to remove the sodium sulphate would be by treatment with barium which would cause the barium and sulphate to unite as barium sulphate, while the sodium would be precipitated but would cause no trouble in freezing. The only way that sodium chloride could be removed from the water would be by nitrate of silver treatment which, of course, would not be commercially feasible. Apparently the only solution at your plant is to change from a raw-water system to a distilled-water system or obtain a different water supply.

Feeding Boiler Compound

What are the methods of supplying boilers with compounds for prevention of scale? *A. L. M.*

Compounds may be introduced into the boiler continuously or intermittently, but small quantities introduced continuously or at short intervals are more effective than large quantities at long intervals. For continuous feeding, connect the suction side of the feed pump with a small reservoir containing the compound in solution, arranged like an ordinary cylinder oil lubricator. In large plants it is common practice to use an independent pump to force the solution into the feed line and thus relieve the regular feed pump of contact with the boiler solution. Intermittent feeding of the compound is performed by temporarily connecting the regular feed-pump suction with the reservoir containing the compound.

Perfect Vacuum not Obtainable with Piston Pump

Why cannot a perfect vacuum be formed in the suction chamber of a piston pump? *L. C.*

A perfect vacuum cannot be obtained on account of the presence of air or vapor initially present in the suction chamber or liberated out of water or other liquid in communication with the suction chamber. When air or vapor fills the suction chamber, with each succeeding suction stroke of the pump piston, the air or vapor expands to the volume of the suction chamber and connected passages and volume of the piston displacement. During the return stroke only the volume of piston displacement is discharged. If there is no leakage from the atmosphere, the air or vapor thus remaining in the suction chamber is reduced in pressure by each suction stroke of the piston, but, as it cannot be entirely removed, a perfect vacuum cannot be obtained.

Thermal Efficiency and "Rankine Efficiency" of Engine

What is the thermal efficiency of a condensing engine operating with an economy of 13 lb. of dry steam per horsepower-hour, initial pressure 125 lb. gage and exhaust pressure 26 in. vacuum, and what would be the ratio of the thermal efficiency to the efficiency of a perfect engine working on the Rankine cycle between the same limits? *A. J. M.*

The heat equivalent to one horsepower-hour is (33,000 × 60 ÷ 778 = 2,545 B.t.u. From the steam tables it is seen that a pound of steam at the pressure of 125 lb. per sq.in. gage, or 140 lb. absolute, contains 1,192.2 B.t.u. and when condensed at 26 in. vacuum the liquid would contain 94 B.t.u. Hence the thermal efficiency would be $\frac{2{,}545}{13\ (1{,}192.2 - 94)} = 0.178$ or 17.8 per cent.

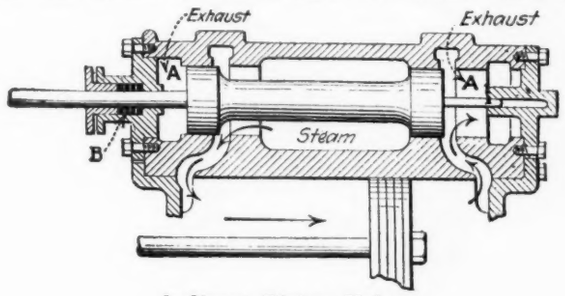
The thermal efficiency of a perfect engine working on the Rankine cycle is the ratio of the heat changed into work per pound of steam, if expended adiabatically, to the heat necessary to convert a pound of feed water from the temperature of the exhaust into steam of the pressure and quality supplied to the engine. From the total heat entropy diagram it may be found that by adiabatic expansion of a pound of dry saturated steam from 140 lb. absolute to 2 lb. absolute there would be 1,192.2 — 914 = 278.2 B.t.u. changed into work; and as the heat in the feed water is 94 B.t.u. and the heat required to convert a pound of the feed water into steam would be 1,192.2 — 94 = 1,098.2 B.t.u., the thermal efficiency of a perfect engine working on the Rankine cycle under the stated conditions would be $\frac{278.2}{1{,}098.2} = 0.253$, or 25.3 per cent. Therefore the ratio of the thermal efficiency to the thermal efficiency of a perfect engine working on the Rankine cycle between the same limits would be 17.8 ÷ 25.3 = 0.703.

This ratio of the thermal efficiency of an engine to the thermal efficiency of a perfect engine working on the Rankine cycle between the same limits is known as the "Rankine efficiency."

Piston Valve with Inside Admission

In a piston-valve engine with direct-connected valve, why does the eccentric follow instead of leading the crank? *R. N.*

With direct connection of the eccentric to the valve stem the eccentric must follow the crank when an indirect valve is used. This type of piston valve is shown in the illustration. Steam is taken in the middle of the valve and exhaust takes place at the ends of the valve into the exhaust passages *AA*, thus reversing the method of distribution of the steam by an ordinary D slide valve. The principal advantages of this arrangement are that only the ends of the valve are subjected to the cooling effect of the exhaust and the valve-stem stuffing box *B* requires to be kept only tight enough to prevent leakage of exhaust steam.



Indirect Piston Valve

Size of Pump Suction Line

What determines the proper size for a pump suction pipe? *R. G.*

The minimum of size would be limited by the loss of pressure of the water from pipe friction. With the usual number of bends and fittings in suction lines, the size of pipe should be sufficient for a velocity of the water not in excess of 240 ft. per minute when pumping at the maximum rate. The loss of pressure from friction is not materially reduced from having the suction pipe large enough to obtain a less velocity, and an excessive size of suction pipe is objectionable, as the lower the velocity of the water the longer the time required for it to traverse the suction line with reduction of pressure, and the greater the quantity of air liberated.

[Correspondents sending us inquiries, should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

Here and There in the Power Plant

Sidelights on things generally used but less generally understood

Low-Head Heat

HEAT is often spoken of in a way that would indicate that one B.t.u. is as good as another. Actually, this is far from being the case, at least so far as power production is concerned. In estimating the value of the heat in a body, its temperature must be taken into consideration. A few illustrations will make the truth of this statement evident.

A large power plant is situated, let us say, on the bank of a river. The boilers are producing each hour one million pounds of steam at 200 lb. pressure and 200 deg. superheat. During the same period one billion pounds of river water flows by at an average temperature of 60 deg. A simple calculation will show that the water represents more heat than the total output of the boiler plant.

More Heat in River

Taking the customary basis of water at 32 deg., each pound of the steam has a total heat of 1,310 B.t.u., so that the total hourly boiler output is $1{,}310 \times 1{,}000{,}000 = 1{,}310{,}000{,}000$ B.t.u. On the same basis each pound of river water contains $60 - 32 = 28$ B.t.u., giving a total of $28 \times 1{,}000{,}000{,}000 = 28{,}000{,}000{,}000$ B.t.u. per hour for the river—21.4 times as much as for the boilers.

The objection may be raised that neither of these figures represents the total amount of heat present, since both are measured above water at 32 deg.—a purely arbitrary, though convenient, point. To be strictly scientific, the total amount of heat in a pound of steam or water at any given condition would be the heat required to bring a pound of ice at a temperature of absolute zero (—460 deg. F.) up to the given condition. No one knows how much heat this would take except that the amount would be comparatively large. Suppose that the letter X is used to represent the amount of heat above absolute zero in a pound of water at 32 deg. Then the true total heat in a pound of the boiler steam would be $1{,}310 + X$, and in a pound of river water $28 + X$. If these quantities are multiplied by the respective weights of one million pounds and one billion pounds, it is evident that, whatever the value of X, the ratio of the heat in the river water to that in the boiler steam must be increased over that figured on the basis of 32-deg. water.

Yet the enormously greater amount of heat represented by the river flow has no value for power purposes, while that in the steam is evidently of considerable value. Why is this? The answer is found in the relative temperatures. The heat in the river is low-temperature heat or "low-head" heat. The process of turning heat into power involves a fall of temperature, and if there is no way of obtaining such a temperature fall, no part of the heat can be turned into work.

Imaginary Low-Temperature Plant

Leaving out of consideration for the moment the ordinary practical considerations such as cost of apparatus, convenient location, etc., it is possible to conceive of circumstances where the heat of the river could be made to produce a large amount of power. Imagine the river transported without change of temperature to the polar regions where the surrounding temperatures were far below zero. There the river water might be used to evaporate some highly volatile fluid which could be expanded through turbines to air-cooled condensers and thus produce a large amount of power. Practically the idea may be ridiculous, but the scientific possibility exists.

This thought serves to illustrate the law that heat is useful for power-production purposes only where other bodies at lower temperatures are close at hand. Moreover, the amount by which the temperature of the hot body exceeds the lowest available is a rough measure of the extent to which the heat can be turned into power. Thus the power obtained from a given weight of steam in a condensing plant increases as the temperature of the circulating water is decreased.

Low-Head Heat Worth Less for Power Production

On account of this characteristic, the terms low-head and high-head heat have come into general use in discussions of power-plant heat balance. For example, in the average large condensing station about half of all the heat in the coal fired is thrown away in the circulating water. This loss is in the main unrecoverable for power purposes because this heat has a low head—that is to say, a low temperature. The circulating water cannot be pumped into the boilers for the simple reason that the condensate supplies about all the feed water required. Neither can its heat be transferred to the feed water in closed heaters for the obvious reason that heat will not flow from a colder to a warmer body even though the colder body (on account of its greater weight) actually contains a much greater total amount of heat than the warmer body.

The condensate temperature is therefore the zero line for heat value in a steam power plant. Heat at that temperature is worth nothing for power production, although it may have cost a lot. Heat at a temperature 20 deg. above that of the condensate is worth more; at 40 deg. above it is worth still more and so on progressively.

This is the fundamental principle involved when feed water is heated in successive steps by steam bled from the main turbine. If a feed temperature of 200 deg. were desired, all the heating could be done in a single open or closed heater supplied with steam bled from the turbine at about atmospheric pressure (212 deg. steam), but this would be wasteful because the first stages of this heating could have been done just as well by steam that had expanded to a lower pressure and thus produced that much additional power in the turbine. Economy would be increased by bleeding the turbine at several points. Steam bled at the lowest pressure would first be used to heat the condensate to a temperature as near as practicable to that of the bled steam. Only a limited amount of this low-pressure steam could be used. Then a bleeder heater taking steam at a somewhat higher pressure would put some more heat into the feed water.

Bleeder Heating

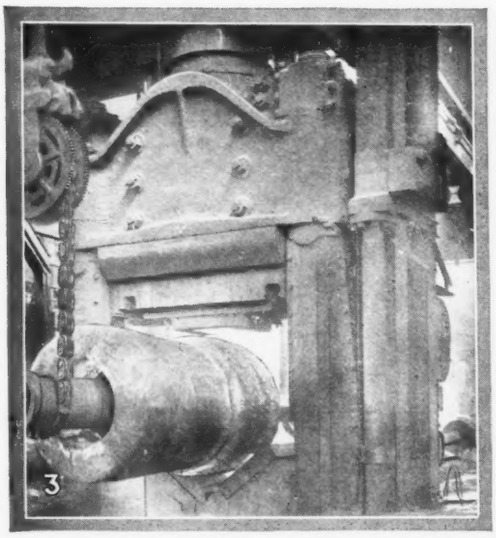
The theoretical ideal would be to heat the feed water by an infinite number of bleeder heaters, so that each stage of the heating would be done with steam from which the maximum amount of power had first been extracted. In practice it is found that from two to four bleeding points is as close an approach to the ideal as is commercially practicable at the present time.

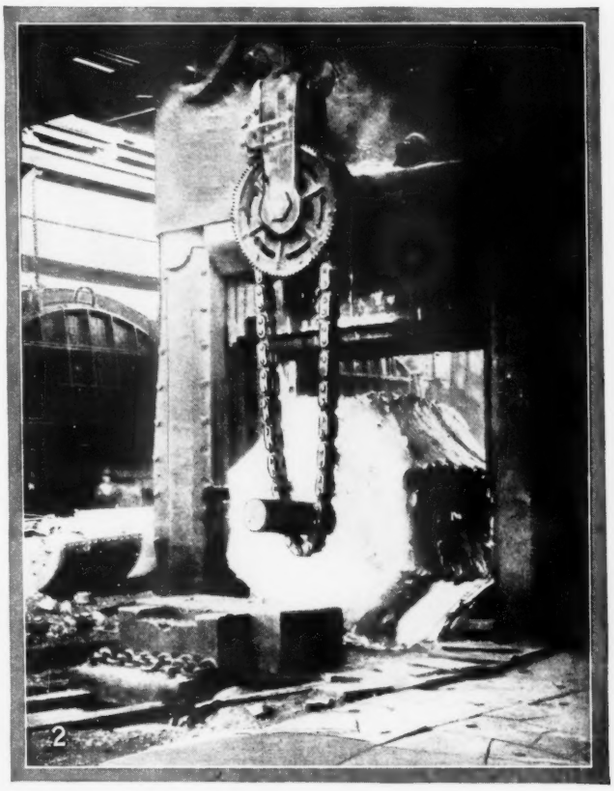
The recoverable value of any heat wastes around the plant is largely determined by the temperature. For example, the cooling air from the main-unit generators contains a considerable amount of heat. By the use of tubular coolers through which the main condenser condensate is circulated, this heat can be returned to the system, but it is a serious error to consider the heat thus put into the feed water as a clear saving. There is already far more low-head heat available in the plant than can possibly be used. The feed heating done by the generator cooling air could be done by steam bled at a low pressure, the only cost of bleeding this steam being the value of the small amount of power it could develop if allowed to complete its expansion in the turbine from the bleeder point to the condenser.

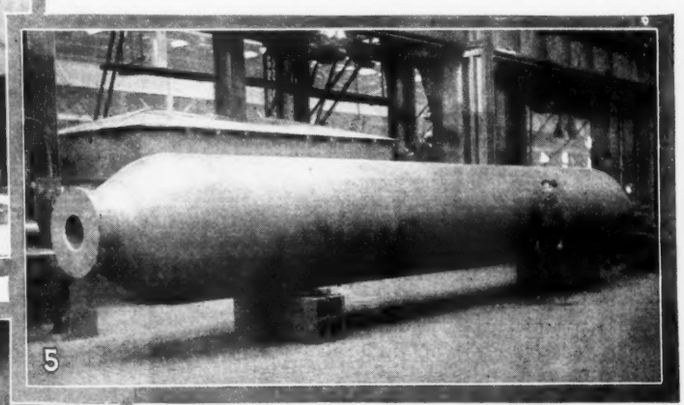
Generator Air Coolers

Of course if it is desired to cool the air so that it may be used in a closed cycle for fire-prevention reasons, it may be worth while to put the heat into the feed water, but heat recovery alone would rarely warrant the installation of a generator air cooler.

Forging Drum for 1,200-lb. Boiler







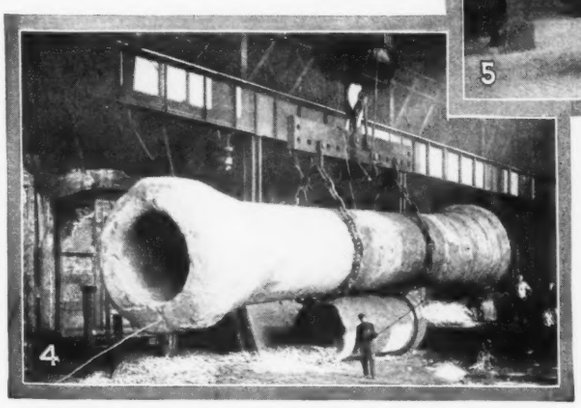


Fig. 1 — Open-hearth, 78-in. 262,000-lb. hexagonal ingot. This was cut hot down to a block 156 in. long.

Fig. 2—After upsetting under a 9,000-ton hydraulic press, the block was trephined with a 23½-in. hollow punch and swung in the press on a mandrel.

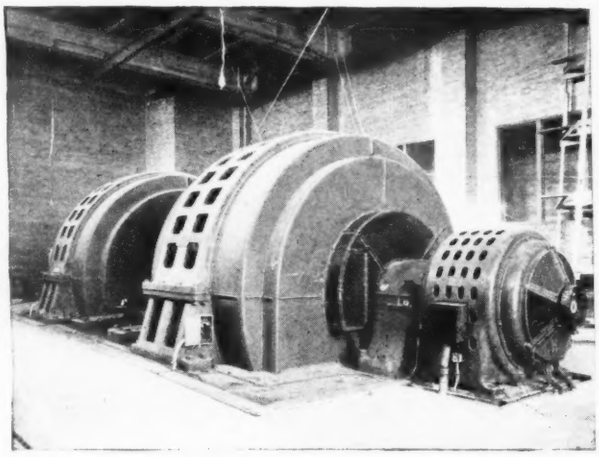
Fig. 3—The forging was then drawn in "V" dies to 45 in. inside diameter and 58½-in. outside diameter.

Fig. 4 — After annealing, testing, machining inside and out, reheating and closing in the ends, the drum was re-annealed above the critical temperature. The ends were then bored to size.

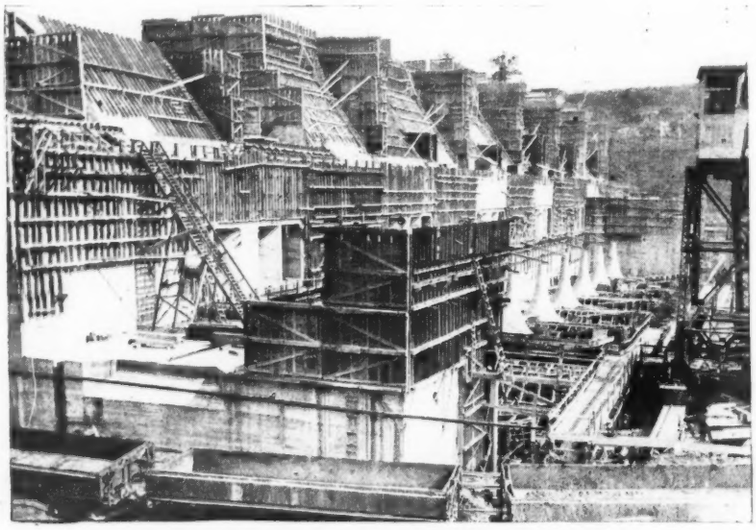
Fig. 5—Finished drum (weighing 88,475 lb.) ready to be built into the 1,200-lb. boiler for Weymouth, Mass. This drum is 34 ft. long (over-all), 4 ft. inside diameter, with walls 4¼ in. thick in the body and 8½-in. thick at the manholes.

Photographs furnished by the Midvale Steel Co.

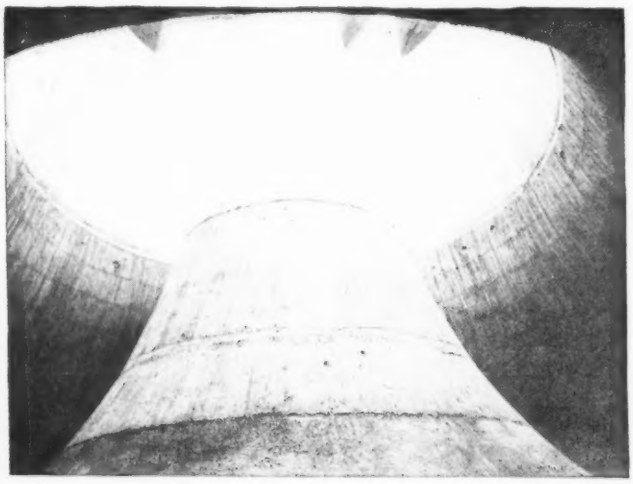
Storage pile of hog fuel, Portland Railway, Light & Power Co., sufficient to generate 22 million kilowatt-hours



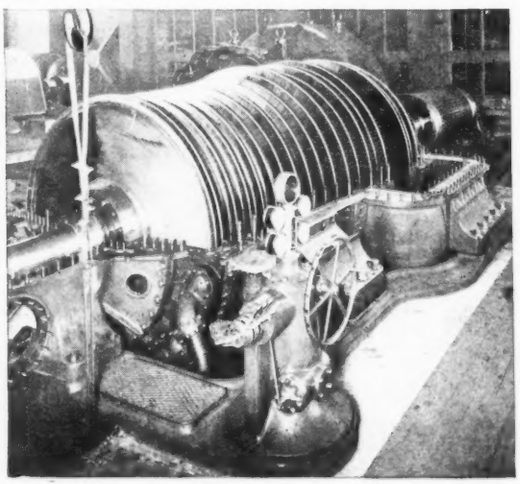
New 37,000-kva. frequency changer at Hell Gate ties 60-cycle and 25-cycle systems



Construction view of Muscle Shoals power house

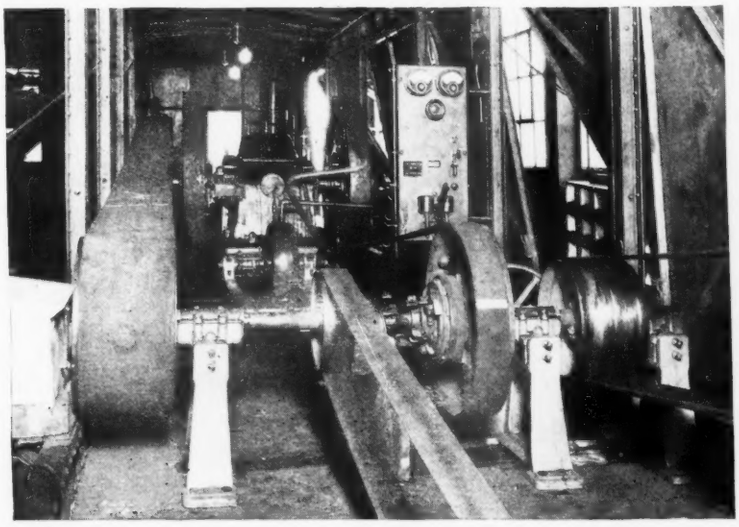


Looking up into draft tube of a Muscle Shoals unit showing the Moody hydraucone

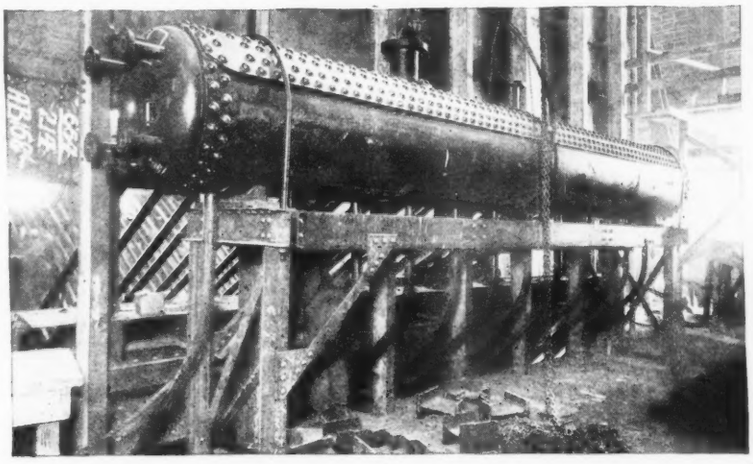


One of the 62,500-hp. turbines built by Ford for use in his own works

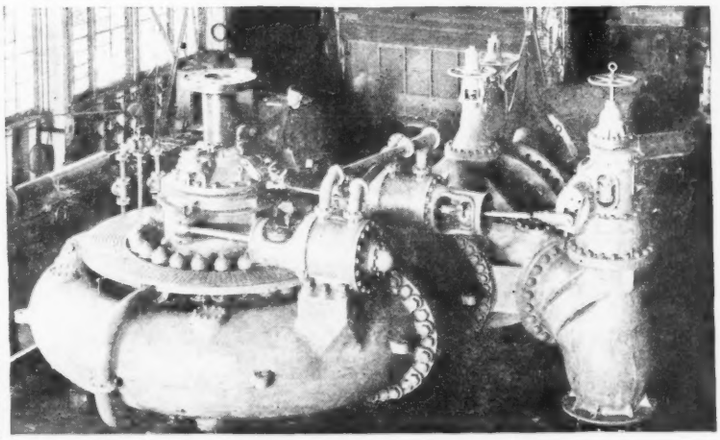
Cooling tower on roof of B. F. Goodrich plant at Akron is 60 ft. high



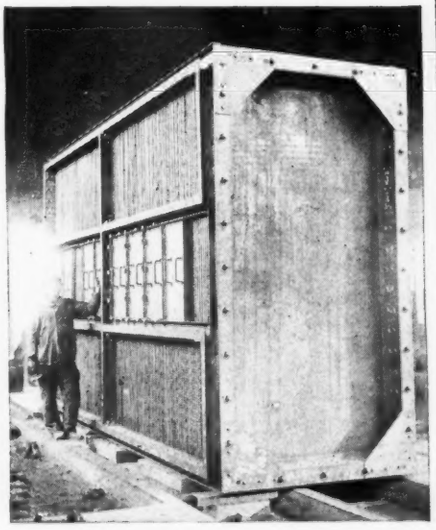
Oil-engine power plant on railway car. This is part of a portable oil refinery recently completed by the Graver Corp.



Water-screen drum on one of the boilers at Trenton Channel Plant, Detroit



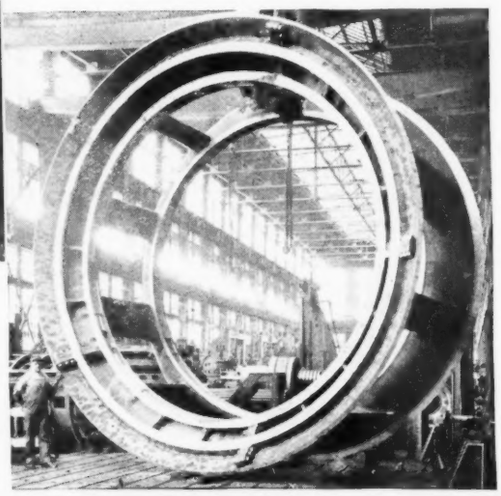
Highest-head reaction turbine—35,000 hp. 860-ft. unit for Oakgrove Development, Portland, Ore.



Prat air preheater built in France for N. Y. Edison Co.

Plaque presented to Mortimer E. Cooley, past president of the American Engineering Council, by his former associates on the council

R. Sanford Riley proves it can be done



On right, cast steel speed ring of 40,000-hp. turbines for Quebec Development on Saguenay River

Dinner to Ambrose Swasey on occasion of presentation of John Fritz Medal

Seated, left to right: W. E. Kelly, F. B. Jewett, Elihu Thomson, Gen. Crozier, Ambrose Swasey, C. F. Rand, B. B. Thayer, J. R. Freeman, W. L. Saunders, Waldo Smith, G. B. Davison, N. W. Craver, F. H. Sharpless, C. W. Rice, G. S. Webster, F. R. Low, W. L. Warner, F. J. Miller, J. J. Carty, W. F. M. Goss, J. V. W. Reynders. Standing, left to right: A. D. Flynn, F. L. Hutchinson, H. B. Sargent.

Report of Committee on Dust-Explosion Hazards

AN ADVANCE copy of the report of the National Fire Protection Association Committee on dust-explosion hazards contains the following proposed regulations governing pulverized-fuel systems. These regulations are still tentative and are subject to change before final adoption by the association. An abstract of the regulations is given herewith.

Pulverized-fuel systems are of various types; all involve the hazard incident to the creation and possible liberation of combustible dusts unless properly designed, constructed and operated. In general they may be arranged in three classes as follows:

Class A Systems—Indirect, or those in which the fuel is intimately mixed with air at the point or points where used and involving storage bins at points of consumption.

Class B Systems—Direct, or those in which the pulverized fuel is fed to a fan by which it is blown as a combustible mixture through large pipes to furnaces or other points of combustion. In the case of circulating systems of this class, the unused fuel is returned to the initial point to again be blown through the line.

Unit Systems—Those in which the fuel is pulverized at or near the point or points of use and delivered directly from the pulverizer into the furnace by means of fan or blower, which may be an integral part of the apparatus, the air being admitted in the apparatus or in conjunction with the fuel. Systems of this type do not employ bins.

Installation of pulverized-fuel systems should be under the supervision of engineers qualified by experience in the design, construction and operation of such equipment.

Note: The term "approved" shall be interpreted as by the Inspection Department having jurisdiction. The terms "adequately," "effective" and "securely" shall be interpreted as conditions subject to the approval of such Inspection Department.

These regulations are designed for application to new installations and when making alterations or extensions to existing equipment. They are not retroactive.

General Regulations, Class A and Class B Systems

1. Location: (*a*) The process of pulverizing fuel shall preferably be accomplished in a separate detached building used for no other purpose.

(*b*) Where this is not feasible, this process shall be carried on in a separate room or separate floor used for no other purpose. This section shall be separated from the rest of the building by masonry walls and floors.

(*c*) Driers may be installed in boiler rooms of fire-resistive construction, cut off in a standard manner from the rest of the plant.

(*d*) Except for the passage of shafts, pipes and closed conveyors, these walls and floors shall, where practicable, be unpierced. Where feasible all communication between the pulverizing plant and the rest of the building shall be from the outside or by means of fire-resistive stairways enclosed by masonry walls.

2. Construction: (*a*) The building containing pulverizing equipment shall be constructed of incombustible materials and specially designed (1) to secure minimum lodgment of dust; (2) so that all interior parts of the building on which dust may lodge may be cleaned readily; and (3) to relieve the force of an explosion through skylight, window or explosion doors.

(*b*) Depending on local conditions, either light or heavy type of building construction may be used for housing pulverizing equipment.

(*c*) A portion of the exterior walls and roof (considered in lieu of an exterior wall) equal to not less than 10 per cent of the combined area of the inclosing walls shall be of light incombustible material, preferably thin glass.

(*d*) In buildings of light construction the frame should be preferably of steel with light non-bearing walls (except fire walls), constructed of such materials as stucco on metal lath, tile, metal or equivalent incombustible materials and with roof of monitor or gable type, and all secured in such a manner as to give way readily under pressure of explosion.

(*e*) In order to prevent accumulations of dust, the design of the buildings shall be such and the structural members so shaped and assembled or protected as to prevent the least possible extent of surface on which dust can lodge. Access must be provided for cleaning all parts of building on which dust may accumulate.

(*f*) Wired glass, if used, shall be in sash so hung that they will readily swing out in case of an explosion. Such sash shall not be secured; where thin glass is used, this form of hanging is not necessary.

3. Ventilation and Dust Collection: (*a*) All buildings or parts of buildings in which the processes of pulverizing are carried on shall be well ventilated to the outer air.

(*b*) The atmosphere of the room shall be kept as free as possible from suspended or floating dust by maintaining all apparatus in a dust-tight condition.

(*c*) Static Dust—Good housekeeping is a factor of the utmost importance. To this end every coal drying and pulverizing plant shall be kept free from even small accumulations of coal dust. It is recommended that all interior surfaces be either whitewashed or painted white and cleaned at sufficiently frequent intervals to prevent such accumulations of coal dust.

Interior surfaces shall be cleaned in such manner that no dust will be scattered or distributed. To this end it is recommended that dust removal be accomplished by an adequate pneumatic or vacuum sweeping system. The use of compressed air for blowing dust from motors or other equally inaccessible places is recommended, but the general use of compressed air (except in connection with water spray) for blowing dust from walls and other interior surfaces is prohibited.

(*d*) Because of the hazard attending the operation of motors and the use of flexible electric cable in coal-pulverizing plants, the use of portable vacuum cleaners or air compressors is not recommended. Portable tanks containing compressed air may be used provided no electrical equipment is operated inside of the pulverizing room in connection therewith.

(*e*) Pneumatic sweeping systems, if installed, shall comply with the following general requirements:

1. Systems shall be of sufficient power and capacity to accomplish effective results.

2. Nozzles and handles shall be constructed of non-ferrous metal fiber or other non-sparking material.

3. Hose, nozzles, handles and other metal parts shall be electrically grounded to the piping system and the piping system effectively grounded to the earth.

4. Dust separation shall take place before the dust reaches the exhauster. The separator or separators shall accomplish practically complete separation as there should be no perceptible discharge of dust from the exhauster unless discharge is carried outside of the building. The dust entering the separator shall not directly strike a metallic surface.

5. The motor and separator should preferably be located outside of the pulverizing room.

4. Pulverizer: All pulverizer mills shall be safeguarded against the hazard of fire or explosion and be operated under competent supervision. Power for operation of pulverizing plant shall be controlled remotely at a readily accessible location and at the mill. Pulverizers, shafting and other metal parts of equipment and belts shall be electrically grounded in an effective manner.

5. Magnetic Separator: (*a*) A magnetic separator shall be provided for each system employing pulverizing mills and shall be installed ahead of the pulverizer.

(*b*) The magnetic separator shall be of such size as to expose and insure the removal of tramp iron or other magnetic substances.

6. Electricity for Light and Power: All electrical equipment for light and power in pulverizer house shall conform with the National Electrical Code. Provision shall be made for remote control in order that current for light and power may be cut off in an emergency without entering pulverizer house.

7. Dust Collectors: All dust collectors, except those of cloth type, shall be constructed of non-combustible material and if not within the drying or pulverizing department shall be located in a separate room, properly vented to a safe point outside of the building.

8. Vents: Safety relief vents shall be liberally provided on all pulverizing equipments, particularly at the mill in the discharge therefrom; at elevator heads and at every storage bin for pulverized fuel. Storage-bin vents shall have a cross-sectional area sufficiently

large to permit the separation of air from fuel without building up an abnormal pressure within the bin. Vents taken off pipes and flues shall be of at least the same area as the pipes or flues vented; they shall lead by the most direct practicable route to the outside air and shall not deviate more than 22½ deg. from the direction of the pipe or flue from which they lead.

9. Blowers Handling Fuel in Suspension: (*a*) Blowers shall be installed on proper foundations and secured in a substantial manner. They shall not be used for any other purpose, but this shall not be construed as prohibiting the use of a blower as a means of supplying secondary air also.

(*b*) Bearings of blowers handling fuel in suspension shall not extend inside of blower casings or ducts.

(*c*) All connections between discharge end of blower and main duct shall be made so as to prevent leakage of fine dust.

10. Driers: (*a*) The drying department shall be separated from the pulverizing department by means of incombustible partitions constructed of material having a fire resistence of not less than one hour in accordance with standard specifications for fire tests and materials of construction.

(*b*) Driers shall be of a type such that the products of combustion of the heating unit shall not come in contact with the fuel being dried, except at a distance of at least one-half the length of the drier, and in no case within 12 ft. of the fuel bed.

(*c*) Coals (other than Anthracite and Coke): Drying coals (other than anthracite and coke) increases their tendency to spontaneous ignition. The quantity of dried coal, either unground or pulverized, stored in any plant, should be kept as small as possible without interfering with the continuity of plant operations. In all cases operating schedules shall be so arranged as to leave no dried unground coal in the plant when the mills are shut down for a period of four hours or more.

Pulverized coal exceeding a temperature of 150 deg. F. shall not be stored in any bin in connection with a Class B system.

In order to assist in regulating the temperature of the coal, in connection with Class A and Class B systems, a recording thermometer shall be installed at the discharge end of the drier, the bulb end of which shall be as close to the coal within the drier as practicable.

(*d*) Every drier shall be designed to prevent gases of combustion from entering its shell when not in operation.

11. Dried coal elevator shall be of non-combustible construction, dust-tight and provided with a safety relief vent to the outer air.

12. All pulverizing mills and driers shall be constructed as dust-tight as practicable, and so operated as to avoid leakage of dust.

13. Pipe Lines: (*a*) All pipes connecting air mills, cyclones and mill bins should preferably be constructed of lap-welded steel pipe, seamless steel tubing or of butt-welded sheet steel. Where butt-welded sheet steel is used, it should be No. 10 gage or thicker.

(*b*) Fittings shall be constructed either of cast iron or butt-welded sheet steel not less than No. 10 gage.

(*c*) Where cast-iron flanged fittings are used, the flanges shall conform to the 125-pound American Standard in diameter, bolt circle and number of bolts.

(*d*) Where welded sheet-steel fittings are used, they shall be provided with removable wearing plates at all points subject to abrasion.

(*e*) All joints shall be made either by means of standard pipe fittings or by flanges welded to pipes. Such flanges shall be not less than ¼ in. thick and shall conform as to diameter, bolt circle and number of bolts with the 125-pound American standard.

14. Fire Protection: Every building or room containing the foregoing processes shall be provided with approved fire extinguishers in such quantity and of such type as outlined in the Regulations for the Installation, Maintenance and Use of First Aid Fire Appliances.

Class A Systems

15. Transportation Pipe Lines: All pipe lines for transporting pulverized coal between mill bins and points of consumption or storage shall be of standard full-weight steel pipe, and fittings equal to the 125-lb. American standard.

16. Joints and Valves: All pipe joints shall be securely made so as to insure a dust-tight installation. All control, switching and shutoff valves shall be of dust-tight construction.

17. Every coal-conveying line shall be located away from all open flames or open lights of any kind and at safe distance from sources of radiated heat, such as furnaces, ovens, boilers, boiler settings, etc.

18. Storage and Furnace Bins: (*a*) Storage and furnace bins for pulverized fuel shall be located as far as consistent with operating requirements from furnaces, and away from open flames or open lights of any kind. Location shall be such that no radiation from furnaces, boilers, steam pipes or flues, or other heating appliances, can materially raise the temperature of the contents of the bin.

(*b*) All bins shall be of non-combustible material so constructed as to present a smooth surface on the interior, and so shaped that no material will be left in the corners under normal emptying operation of the bin. Material used in construction of metal bins shall be steel of sufficient thickness to secure ample mechanical strength. Joints shall be riveted, calked or welded; size and spacing of rivets shall be such as to secure a dust-tight joint. Dust-tightness shall also be secured in cases where metal bins are lined with concrete or where bins are constructed of concrete.

(*c*) Except for vent openings all storage and furnace bins shall be normally tightly closed. Those bins which are filled by transporting pulverized coal by means of air, either under pressure or by a fan, shall be provided with means for preventing the transport air from raising a dust cloud within the bin.

(*d*) All bins shall be equipped with a reliable indicating device to warn the operator before the bin is in danger of overflowing without exposing the contents. At no time shall there be any pressure other than that caused by the weight of the fuel in any pulverized-fuel storage bin.

19. Screw Conveyor: Systems using overhead screw conveyors for handling pulverized fuel shall be arranged with driving power applied at the discharge end. Where the length of transfer is too great for a single screw so driven, any additional units shall be similarly driven and so interconnected that the stopping of the last screw in the series will automatically stop the others, or as an alternative for such interlocking the junction point between the two screw conveyors shall be placed outside of the building.

20. (*a*) In no plant shall coal-storage bins, conveying machinery or fuel pipe lines be used as supports for electric lighting or power lines other than those installed in conduit.

(*b*) Machinery and all other parts comprising the crushing, drying, pulverizing and conveying systems shall be electrically grounded in an effective manner.

Class B Systems

21. Piping: (*a*) Distributing piping shall be of suitable metal pipe; flanged joints may be used. Piping and fittings shall be designed to withstand safely the maximum working pressure that may be exerted and so installed as to be adequately safeguarded against mechanical injury.

(*b*) In each switch or branch line to burner there shall be installed a suitable check which will be positive in operation.

22. Same as item 16.

23. Same as item 17.

24. Blowers: (*a*) Primary blower shall be operated and maintained at a rate producing a primary air pressure higher than that of the secondary or booster.

(*b*) Motor circuits for primary blower and booster fan shall be protected by the same circuit-breaker switch or other protective device, so that the stopping of either will cause the simultaneous stopping of the other.

25. All main circulating lines shall be free from baffles, valves or any obstruction which might cause an accumulation of pulverized fuel in the line.

26. Storage Bins: (*a*) Same as (*b*) item 18.

(*b*) Cyclone separators shall not be placed directly over pulverized-fuel storage bins, but shall discharge returned coal to the storage bin by means of gravity chutes, screw conveyor or other equally safe method.

27. (*a*) Same as (*a*) item 20.

(*b*) Same as (*b*) item 20.

Unit Systems

28. Pulverizer: Same as item 4.

29. If heated air is admitted to the pulverizer, the heating shall be accomplished by an indirect method.

30. Magnetic Separator (*a*) Same as (*a*) item 5.

(*b*) Same as (*b*) item 5.

31. Electricity as power for operating: Same as item 6.

32. Blower: (*a*) The blower shall be installed on proper foundation and secured in a substantial manner.

(*b*) Same as (*b*) item 9.

(*c*) Same as (*c*) item 9.

33. All pulverizers shall be constructed as dust-tight as practicable

and so operated as to avoid emission of dust.

34. No single apparatus shall supply more than two furnaces.

35. The volumetric capacity of the system, including the housing of mill, mixing chamber (if any), fan and all of the piping, shall not exceed 100 cubic feet unless vented in accordance with the provisions of Section 8 of these regulations.

36. All portions of the system shall be confined within the room or building where the fuel is prepared or consumed.

37. Piping and fittings shall conform to the requirements of Section 13—Pipe Lines.

38. Each discharge pipe shall be provided with positive shutoff gate or control.

39. When two discharge pipes from separate pulverizers deliver to the same furnace through the same nozzle, a valve shall be provided at the junction of the discharge pipes which will automatically shut off the discharge pipe which is not in use.

40. Every vertical or nearly vertical pipe which delivers the fuel to the furnace through a down turn shall be provided with a safety relief vent, as provided for in Sect. 8 of these regulations.

41. No turn at an angle greater than 45 deg. shall be permitted in any pipe unless the pipe is vented as required in these regulations.

42. If a crusher, drier or other equipment is also used, installation shall be in accordance with the general requirements for Class A and Class B systems.

Geological Survey Completes Its Records of Water Powers in United States

THE Geological Survey, Department of the Interior, has just brought up to date its record of developed water power in the United States, which shows that there are now about 3,200 water-power plants of 100 hp. or more, having a total capacity of installed water wheels of 9,086,958 hp., an increase of about 1,160,000 hp., or nearly 15 per cent over the total in 1921, which was 7,926,958 hp. Of the present total 81 per cent is in public-utility plants and 19 per cent in manufacturing plants. The corresponding percentages in 1921 were 78 and 22.

DEVELOPED WATER POWER IN SPECIFIED DIVISIONS OF THE UNITED STATES IN 1921 AND 1924

Division	Percentage of Total in U. S. 1921	1924	Difference
New England	16.5	15.3	—1.2
Middle Atlantic	18.7	19.1	+.4
East North Central	9.3	9.1	—.2
West North Central	5.6	5.1	—.5
South Atlantic	13.6	14.3	+.7
East South Central	3.1	3.8	+.7
West South Central	.2	.2	0
Mountain	10.4	9.7	—.7
Pacific	22.6	23.5	+.9

New York, with 1,542,983 hp., is still the leading state in developed water power; California, with 1,451,830 hp., is a close second; Washington, with 480,356 hp., is third; Maine, with 473,188 hp., is fourth; and North Carolina, with 431,500 hp., is fifth, displacing Montana, which ranked fifth in 1921.

Water-power development in the New England, East North Central, West North Central, and Mountain States has not kept pace with that in the other parts of the United States, as Table I shows.

A new estimate has been made of the potential water-power resources of the United States including Alaska, Porto Rico and Hawaii, which it is physically feasible to develop under present conditions. The figures given in the estimate show the 24-hour power available 90 per cent of the time and 50 per cent of the time at 70 per cent over-all efficiency at both developed and undeveloped sites.

For districts where reservoirs are already built or where detailed field examinations show that such storage is feasible, these estimates have been used. This estimate also assumes that stored water will be used to equalize as far as possible the flow of Colorado River below the mouth of Green River. The estimate includes half of the potential power of Niagara River and of the international section of St. Lawrence River, though an international agreement is necessary to permit the full use of these resources.

The present estimate is based largely on reports that include only feasible sites, and it therefore represents the potential power that can be developed when a market is available, yet it does not differ very materially from the estimate made in 1908. Allowing for the difference in assumed efficiency and for the inclusion in this estimate of the United States share of the potential power on Niagara and St. Lawrence rivers, the present estimate of the potential power available 90 per cent of the time is about 21 per cent higher than the estimate of 1908, mainly because of the assumed use of stored water at places where detailed examinations and surveys have shown the existence of good reservoir sites. For the same reason the estimate of power available 50 per cent of the time is 4 per cent higher.

Washington stands first among the states in potential water power, for power available both 50 per cent of the time and 90 per cent of the time, followed closely by Oregon, California and New York. A large proportion of the potential power in New York is available continuously owing to the equalization of the flow of Niagara and St. Lawrence Rivers. The same is true of Arizona, whose water-power resources are mainly on the Colorado River, where the flow can be controlled.

The estimate of the potential water power in Alaska of 1,000,000 hp. for 50 per cent of the time and 2,500,000 ft. for 50 per cent of the time, which is believed to be conservative, is based on a report covering southeastern Alaska and on a general knowledge of the conditions in the remainder of the territory. The developed water power in this territory is placed at 40,000 hp. In Hawaii the developed water power is 25,000 hp., and it is estimated that the potential power is 100,000 hp. for 90 per cent of the time and 200,000 hp. for 50 per cent of the time. In Porto Rico the developed water powers amount to 15,000 hp., and the total developed and undeveloped resources are placed at 19,000 for 90 per cent of the time and 28,000 for 50 per cent of the time.

The percentage of the total potential power of the United States that has already been developed can be estimated only in a rough way. The capacity of waterwheels at developed sites in Maine, New Hampshire, Vermont and Massachusetts amounts to 131 per cent of the power available 50 per cent of the time at those sites. The wheel capacity in Massachusetts is nearly double the potential power for 50 per cent of the time at 70 per cent efficiency. The developed sites in Canada from coast to coast have an average wheel installation 30 per cent greater than the power available during the six months of greatest flow. Assuming that all sites may eventually be developed to a point where the wheel capacity is 131 per cent of the power available 50 per cent of the time, the installed capacity will reach 72,000,000 hp. The present installed capacity of plants of 100 hp. or more is 9,087,000 hp., and on the above assumption of the ultimate installed capacity, about 12.5 per cent of the potential water power of the country has now been developed.

DEVELOPED AND POTENTIAL WATER POWER IN THE UNITED STATES IN 1924

Division and State	Capacity of Waterwheels Installed in Plants of 100 Hp. or More: Total No. of Plants	Total Capacity in Hp.	Public Utility and Municipal No. of Plants	Public Utility and Municipal Capacity in Hp.	Manufacturing and Miscellaneous No. of Plants	Manufacturing and Miscellaneous Capacity in Hp.	Potential Water-Power Resources of the United States: Available 90 per cent of the time Hp.	Per Cent	Available 50 per cent of the time Hp.	Per Cent
United States	3,211	9,086,958	1,390	7,348,197	1,821	1,738,761	34,818,000	100.00	55,030,000	100.00
New England	1,228	1,387,364	249	644,831	979	742,533	998,000	2.87	1,978,000	3.60
Middle Atlantic	607	1,731,881	228	1,408,173	379	323,708	4,317,000	12.40	5,688,000	10.35
E. No. Central	342	829,854	212	625,826	130	204,028	737,000	2.12	1,391,000	2.53
W. No. Central	183	459,736	117	376,864	66	82,872	871,000	2.50	1,844,000	3.35
South Atlantic	259	1,295,978	129	1,045,728	130	250,250	2,476,000	7.11	4,464,000	8.11
E. So. Central	50	345,584	32	323,816	18	21,768	1,011,000	2.90	2,004,000	3.64
W. So. Central	27	15,727	12	12,515	15	4,212	434,000	1.25	888,000	1.61
Mountain	226	880,783	178	860,937	48	19,846	10,736,000	30.83	15,513,000	28.19
Pacific	289	2,139,051	233	2,049,507	56	89,544	13,238,000	38.02	21,260,000	38.63

According to *Commerce Reports* expert reports on Austria's water-power requirements recommend as the indispensible minimum for the next 15 years the development of 60,000 hp. per year, or altogether 900,000 hp. This is thought to be within reasonable limits as shown by the example of Switzerland and Bavaria. The only difficulty is the raising of the necessary capital.

Muscle Shoals Bids Compared by General C. C. Williams

Senate Committee Consider Ford Bid—New Bid from Union Carbide Company—F. G. Waldo Questions Water Power Act

MUSCLE SHOALS has occupied the center of the stage in Washington during the last week. The Ford offer was explained at length by Mr. Ford's engineer to the Senate Committee on Agriculture and Forestry. F. G. Waldo, of a Tennessee River land developing company, attacked the Federal Power Act in a vigorous fashion, saying:

"The Federal Water Power act, as a means for protecting the public interest at dams on navigable streams, is an absolute failure, for the provisions cannot be enforced except as to navigation where no public lands are concerned.

"If the War Department concludes that a private dam in a navigable stream will not interfere with the navigation, then it is not within the power of the department to withhold its expressing such an opinion and granting such a permit.

"The Federal Power Commission is collecting 25 cents per horsepower annually for administering an act that could better be administered by the Chief of Engineers without any annual charge."

The Union Carbide Co. sent in a bid of $120,000,000 for the lease of the dams and nitrate plants. The purchase of a new patent for an improved process of making fertilizer from nitrogen taken from the air has made it possible, according to officials of the company, for this offer to be made. The committee expects to take up the Carbide offer in two weeks.

Gen. C. C. Williams, the Chief of Ordnance, in his testimony, presented comparison of the offers as given below.

The method of comparison set forth in the table is explained as follows:

The period covered has been limited to 50 years following completion of Dam No. 2.

No interest, simple or compound, on payments to the United States has been computed.

The fertilizer agreements of the various offers are not compared because there is no definite basis upon which a comparison may be made. It should be noted that in the case of the Hooker plan and in the case of the Union Carbide Co.'s offer, should fertilizer be made at a loss, the loss will fall upon the government and that therefore the figures shown in the attached table will be reduced by that loss if any.

In dealing with Mr. Ford's figures, there is deducted from the $5,000,000 that he would pay for the Nitrate Plants, the sum of $3,472,488, since this sum would be expended by the government in building a new steam plant on the Warrior River.

In establishing figures for Mr. Hooker's offer, nothing is included for revenues on additional facilities which it is proposed should be constructed at government expense. His plan to increase the size of the No. 2 Steam Plant has been disregarded. This is done for the reason that no proper comparison can be made with such a considerable variation in the property as is involved in the United States expenditure of $6,000,000 to double the size of the steam plant.

In establishing figures for Mr. Hooker's plan, the value of the power is taken from the tabulation made in the hearings of 1922 before the Senate Committee on Agriculture and Forestry on S-3420. These figures appear in the testimony of Major J. H. Burns, Ordnance Department, and are contained in pages 914 to 920.

1. Cost of Dam No. 2 complete, $51,000,000.

2. Cost of Dam No. 3 complete, $27,331,000.

3. Dam No. 3 to be completed three years after Dam No. 2.

4. There will still be $20,000,000 to be expended on Dam No. 2 subsequent to approval of the Ford offer by Congress should the revised offer of May 31, 1922, be approved.

5. There remained $34,000,000 to be expended on Dam No. 2 on May 31, 1922, $17,000,000 having been expended prior to that date.

6. There will be no income to the United States from the manufacture of fertilizer.

7. The steam plant at U. S. Nitrate Plant No. 2 will be sold to the power companies for $4,50,000.

8. The power companies will expend $5,000,000 during the fifty years in maintenance of the U. S. Nitrate Plant No. 2, this amount to be deducted from rent payments.

9. The Union Carbide Co. would use power as follows: 25,000 hp. primary; 13,100 hp. ten months' power average; 11,900 hp. eight months' power average.

10. The income from sale of power under the Hooker plan will be in accord with estimates made in the Ordnance Office (see hearings of 1922 on S-3420, Senate Committee on Agriculture and Forestry, pages 914 to 920).

COMPARISON OF FOUR OFFERS FOR MUSCLE SHOALS PLANTS

	Ford Offer (Interest on $34,000,000 on Dam No. 2)	Power Companies' Offer; Constructed by United States	Hooker Plan	Union Carbide Company's Plan
Dam No. 2	$64,538,384	$87,600,000	$85,479,940 (Includes No. 2 steam plant)	$28,324,200
Dam No. 3	49,841,000	47,809,320	27,794,798	
No. 2 Steam Plant		4,500,000	(Included with Dam No. 2)	
U. S. Nitrate Plant No. 2	1,527,512			7,500,000
U. S. Nitrate Plant No. 1		(Less maintenance expense U. S. nitrate plant No. 2 50 years, $5,000,000)		
Waco Quarry				750,000
Total	*$115,906,896	$134,909,320	$113,274,738	$36,574,200

*This figure is not comparable with the totals for the Ford, Power Companies, or Hooker proposals, since the Union Carbide Company's offer is for only a fraction of the property. The new Carbide offer would amount to $120,000,000 for Dam No. 2 and the existing plant.

Sale for Oil Engines in India

India is becoming a fertile field for kerosene and oil engines. These are as a rule of English manufacture, but American builders of low-priced machines should be able to meet the current prices, which run from $435 for a 4-hp. unit up to $1,771 for a 35-hp. unit. Crude-oil engines are rapidly coming into favor, a 15-hp. unit retailing for $1,546, while a 50-hp. engine sells for $2,750.

Yuba River Development Finished

With the closing of the outlets in the concrete dam on the Yuba River at Bullard's Bar, Calif., the water is backing up the river and its tributaries, creating a lake seven miles long with storage capacity of 32,000 acre-ft.

The dam is 183 ft. high from the bed to the spillway crest, with the bridge 19.5 ft. higher, making a total of 202.5 ft. The length from abutment to abutment is 552 ft. The penstock is eight ft. in diameter, 300 ft. long and leads down to the power house below the dam, which will develop 10,000 hp. at 6,600 volts under 175-ft. head. The transmission line is eleven miles long and will carry 60,000 volts. It will connect with the Pacific Gas & Electric Co.'s system at Colgate power house. Construction of this project began Sept. 1, 1922. The approximate cost was $1,250,000.

Diesel Locomotive Will Have High Efficiency

A new type of Diesel electric locomotive has been built jointly by the General Electric Co. and the Ingersoll-Rand Co. This has been especially designed for switching service and will be given its first practical test by the New York Central in its freight yards at Eleventh Street, New York City.

The power-plant equipment consists of a 300-hp. oil engine directly connected to a 200-kw. generator. The motive power consists of four motors, one of which is geared to each of the four axles. The unit has a total weight of 60 tons, all on the drivers.

The engine is a six-cylinder unit designed to burn fuel oil and having the features of the Price system of direct fuel injection. The fuel is injected into the various cylinders through a distributor by means of a single-acting plunger-type pump which, since the engine runs at 600 r.p.m., has 1,800 delivery strokes per minute.

All parts of the cylinders, cylinder heads and combustion chambers are water cooled by means of a thermostatically controlled water supply. The water from these water jackets passes to a radiator located on the roof, and a thermostat maintains an even temperature regardless of weather conditions. Sufficient fuel can be carried for 48 hours' continuous switching service. The muffler for reducing the noise of the exhaust is also mounted on the roof.

Owing to its high economy, about 0.43 lb. of fuel oil per brake horsepower, the engine is free from smoke, rendering it particularly suitable for service in cities or in places where smoke is objectionable.

The unusual feature of this design is the use of a direct-current generator supplying current to the motors without intervening accelerating resistance. This is accomplished by using a differential series field on the exciter which automatically reduces the generator voltage with the increase in the amount of current drawn by the motors. The speed of the locomotive, therefore, automatically increases as the load is reduced, corresponding to the rise in impressed voltage. This control completely eliminates the possibility of overloading the generator or motors or of stalling the engine.

The control is so arranged that the opening of the throttle by moving the control lever increases the engine speed and at the same time energizes the exciter field, which in turn energizes the generator field. The generator current passes through differentially wound series field to the driving motors, and being opposed to the separately excited field, lowers the generator voltage in proportion to the load. As the locomotive accelerates, the current passing through the differential series field is gradually reduced, the generator voltage automatically increases and speeds up the locomotive. The main excitation of the exciter field is furnished by a storage battery, which also supplies control current and locomotive lights.

It is estimated that the engine will deliver to the drawbar 19 per cent of the heat in the fuel, this being in marked contrast to the steam locomotive, which will average 5 to 7 per cent, and is even better than results obtained with electrified roads, where the efficiency is not over 13 per cent.

Canada Asserts Chicago Seeks Water for Power

According to press reports Canada is unyielding in her attitude in regard to the diversion of water at Chicago by the Sanitary District. "Chicago is trying to carry the water diversion fight to Niagara," said Charles Maguire, president of the Ontario Municipal Electric Association, to a meeting of the association recently. "Chicago will lose. Other cities have spent millions in putting in sewage-disposal plants and they must do likewise." Mr. Maguire continued:

"I don't think that Chicago is alone in this; I believe that somebody else is behind Chicago now and the idea is to question the right of Canada. Canada is accused of taking more water than she should at Niagara Falls. They are trying everything in their power to take the fight to Niagara Falls. We have finally forced them, after a four months' fight, to come out in the open and admit that they want the diversion for the development of power."

Sir Adam Beck said the United States companies have "no more right to take our water than our land, or minerals, or timber." The Supreme Court of the United States, he said, will give a decision before the end of the year, "and I think the Congressmen and government of the United States will limit them to 4,000 sec.-ft., and we will expect to be allowed to use that water at Niagara Falls in excess of an equal division of water between the two countries, and also at the two developments in which we have a half interest on the St. Lawrence River."

Secretary Hughes made public all the correspondence that has passed between the British Embassy on behalf of the Dominion government and the United States on the subject of Chicago's diversion and also dealing with the proposed nine-foot channel in the waterways from the lakes to the Gulf of Mexico. The Dominion asked that the interests of Canada be not overlooked in any waterway projects within the United States that might lower the levels of the Great Lakes and thus interfere with Canada's shipping.

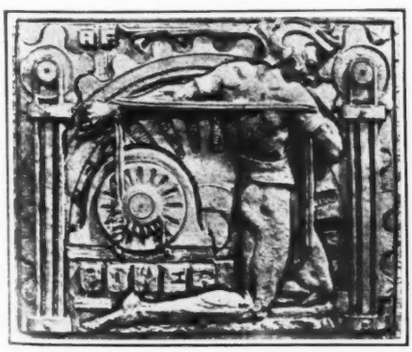
Wabash River Plant To Be Enlarged

The installation of a third 20,000-kw. steam turbo-generating unit with the necessary auxiliaries at the Wabash River plant of the Indiana Electric Corp. has been authorized for immediate construction. The work will be done by Stone & Webster, Inc., Boston, designers and builders of the original station.

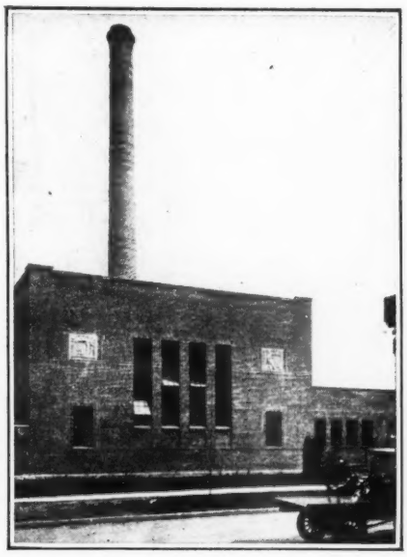
Panels for Power Plant in Oregon

The University of Oregon has set a new fashion in the Northwest in regard to the decoration of power plants. Two bar-relief panels representing "Heat" and "Power," the work of Avard Fairbanks, professor of sculpture at the University, have been placed on the front of the power plant belonging to the university.

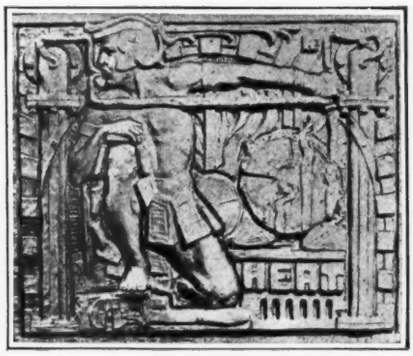
The panels are Aztec in feeling, are bold and strong in treatment and conventional in design. The use of tools and machinery symbolically as well as the flat decisive technique make these panels very distinctive and suited to their purpose.



Panel representing "Power"



View of power plant



Panel representing "Heat"

New York Officials Uneasy About Water-Power Rights

M. E. Connolly, president of the Borough of Queens, New York City, has sent a letter to Attorney General Carl Sherman recently, suggesting that one or more deputy attorney generals be appointed to look into the subject of water power within the State of New York so that the powers of the state may not be interfered with by the federal government. In his letter Mr. Connolly wrote:

"Under the provisions of chapter 346, of the Sessions Laws of 1923, which became a law, with the approval of the Governor, on May 21, 1923, the sum of $75,000 was appropriated for paying the expenses of the Attorney General in prosecuting and defending the rights and powers of the State of New York in connection with water powers within and upon its borders.

"My advice is that up to the present time only about $1,000 of this appropriation has been expended. In view of the recent disclosures which make it appear that there has been malfeasance in the offices of the Department of the Interior and the Department of Justice in Washington, the State of New York should be especially alert in preventing any further encroachments of the federal government upon the rights and powers of the State of New York."

Iguassu Fall Is the Niagara of South America

In South America there is a fall in the Iguassu River 210 ft. high, which has about the same volume of water passing over it as passes over Niagara.

The Iguassu River forms the boundary line between Brazil and Argentina for about 200 miles. This great source of potential power is approximately 1,000 miles from Rio de Janeiro, 700 miles from Sao Paulo and 600 miles from Buenos Aires.

Although the practical development of Iguassu Fall is not feasible at present, it is believed that as the chemical, carbide and other industries requiring large amounts of power are established in the regions nearby, the water power will be utilized for electricity.

Los Angeles Gas & Electric To Build New Plant

As a result of the rapid growth of the electrical business following the expansion of the City of Los Angeles, the Los Angeles Gas & Electric Corp. has started the construction of a new steam-generating plant with an ultimate capacity of 200,000 kw. to assist in caring for the increased industrial and domestic load. The present generating station, which is located in the heart of the industrial section of the city, has reached its maximum capacity. The site selected is at Seal Beach, about 25 miles from the business district of Los Angeles, and at a point where tidal water can be used for condensation. A high-voltage line transmitting power at 110,000 volts will connect the generating station with a receiving sub-station located at the edge of Los Angeles' industrial section, 20 miles distant.

A steam turbine for operation at 350-lb. steam pressure with 50- and 60-cycle generator having a maximum capacity of 35,000 kw. at 60 cycles has been ordered from the Westinghouse Electric and Manufacturing Co. Since the Los Angeles Gas & Electric Corp. operates at a frequency of 60 cycles and yet is at times tied in with the systems of the Municipal Power Co. and the Southern California Edison Co., which operate at a frequency of 50 cycles, the equivalent has been designed for operation at either of these two frequencies. In the present plant this is being accomplished by slowing down the speed of one of the steam turbines and delivering power at 50 cycles to the Southern California Edison Co.

Power for use within the station will be supplied by a 1,250-kva., 2,400-volt generator direct connected to the turbine-generator unit. Two 200-kw. dual-drive exciters and the complete control and switching apparatus complete the equipment.

Westinghouse photo

Falls in the Iguassu River, South America

Belgium Coke and Coal Industries Thriving

The prosperity of the Belgian coal and coke industries during 1923 was very great, surpassing the pre-war year 1913. Production of coal and coke increased over that in 1922. The larger imports of coal in 1923, together with the production of Belgian mines and coke ovens, indicate the prosperity of Belgium's industries last year.

War Department to Plan Power Possibilities of Rivers

Determined opposition has developed to a section in the River and Harbor Bill which is soon to be acted on by both the House and Senate. The section objected to prohibits the issuance of rights for the construction of power dams on navigable rivers or their tributaries until the War Department has adequate information upon which to base a general plan for the most effective improvement of the river, or the system of rivers, as a whole for both navigation and water-power development.

Under this legislation the Chief of Engineers, it is believed, would be in a position to control absolutely the permits granted under the Water Power Act.

Opponents of the proposal intimate that the thought originated with certain interests concerned with the disposition of power at Muscle Shoals. In order to assure the largest possible immediate market for the power at that point, they are said to look with disapproval on the development of other sites in the same general territory.

Interlinking Power Systems Between Detroit and Boston

Plans for the interlinking of electrical power systems between Detroit and Boston, a distance of approximately 800 miles, was announced on May 3 by the Adirondack Light & Power Co. Lines of several other electrical corporations are involved.

The direct interchange of electrical energy between Niagara Falls and Boston will be made possible by the construction of a thirty-mile high tension line between Syracuse and Oneida which will connect the Niagara and New England producing fields for the first time and complete one of the longest high-tension systems in the world.

The lines of four great electrical producing corporations in the East will be utilized in 500 miles of the project between Niagara Falls and Boston, making the Niagara energy available to electrical developments in the Adirondack Mountains and New England steam plants.

The necessity of reciprocity between steam and hydro-electrical development plants is responsible for the present project for the interchange of power.

Figures just issued show that British exports of coal in 1923 totaled approximately 79,500,000 tons, which is an increase of more than 15,250,000 over the quantity exported in 1922.

N.E.L.A. 1924 Convention Program

The National Electric Light Association which will hold its forty-seventh annual convention and exhibition at Atlantic City, N. J., May 19-23, will have an interesting program. Speeches and papers of interest to *Power* readers are:

Tuesday May 20—"Address of Welcome to Atlantic City," Mayor Edward L. Bader; address by President Walter H. Johnson, followed by reports of various committees.

Wednesday, May 21—Address, "Giant Power," by Governor Pinchot of Pennsylvania; address, Hon. Arthur Capper, senator, State of Kansas; address, Hon. Herbert Hoover, secretary, Department of Commerce.

Thursday, May 22—Report of water power committee, Franklin T. Griffith, chairman; address, "The Trend of Court Decisions and Legislation," Carl D. Jackson, counsel, N.E.L.A., New York.

TECHNICAL PROGRAM

Tuesday, May 20—Address, chairman of technical national section, H. P. Liversidge; Report of accident prevention committee, Charles B. Scott, chairman; Report of electrical apparatus committee, H. C. Albrecht, chairman; Report of hydraulic power committee, S. S. Svenningson, chairman; Report of inductive coordination committee, R. N. Conwell, chairman; Report of meter committee, B. Currier, chairman; Report of prime movers committee, Nicholas Stahl, chairman; Report of overhead systems committee, W. G. Kelley, chairman; Report of underground systems committee, W. H. Cole, chairman.

Wednesday, May 21—Address, "Accident Prevention in the Electrical Industry," R. F. Pack, Northern States Power Co.; Award, Insull Medals, Homer E. Niesz, Commonwealth Edison Co.; Address, "Budgeting Engineering Operations," Milan R. Bump, Henry L. Doherty & Co.; Address, "Low-Temperature Distillation of Coal," V. Z. Caracristi, consulting engineer, New York; Address, "A City Transmission Network," John C. Parker, Brooklyn Edison Co.

Thursday, May 22—General problems of management of physical property and the relation of the engineer to such problems; Address, "Economics and the Engineer in Utility Management," Alexander Dow, of the Detroit Edison Co.; Address, "The Engineer's Part in the Future Development and Management of the Industry," John W. Lieb, New York Edison Co.; Address, "Mutual Rights and Duties of Utilities on the Highways," Hon. David F. Simpson, former associate justice, Supreme Court of Minnesota.

Business Sound and Stable Says Mr. Piez

The manufacturer of materials-handling equipment has an unusual opportunity to be informed on business conditions generally, for his product goes into practically every industry. For that reason there is special interest in the production activity of one of the largest manufacturers in that line.

Speaking to a representative of the McGraw-Hill Co. on Monday of this week, Charles Piez, president of the Link Belt Co., with plants in Chicago, Philadelphia, Indianapolis and on the Pacific Coast, and offices in the principal industrial centers, summarized briefly the status of their business.

"Our plants as a whole," said Mr. Piez, "are running at 85 per cent of their normal 48-hour per week capacity. The Philadelphia plant in January, February and March did not show up so well, but there has been a large increase in orders and production in April and we look for a continued upward trend in the Eastern territory. For the Middle Western plants business has been brisk and the same applies, but in increasing measure for the West Coast plant and office.

"Assurance of legislation still further restricting immigration makes materials-handling by machinery necessarily a growing business. Foundries and the coal mines, in particular, are now buying in increasingly large volume.

"Such hesitation as exists on the part of buyers is due, so the buyers themselves state, to the disturbance of the forthcoming election and the Washington political situation. Financial and business conditions of the country generally, however, are sound and stable."

Los Angeles Wants Contract for Boulder Canyon Power

IN THE returns on the vote on the bond issues at Los Angeles, indications point to an overwhelming adoption of the passage of the $8,000,000 water-works bonds and indorsement of the proposition that the city shall contract with the federal government to obtain its share of power at Boulder Canyon in the event of the passage of the Swing-Johnson bill by Congress.

Municipal ownership of the electric power system of the city received two victories in propositions making appropriations toward the expenses of a preliminary survey of the Los Angeles Gas & Electric Corp. property. This would be preparatory to condemnation proceedings which would place the electric lines of the corporation in the hands of th city's power bureau.

Incomplete returns indicated that the $21,000,000 municipal power bond issue had received a substantial majority, though it may lack the necessary two-thirds vote to make it effective.

Program of Refrigerating Engineers Meeting

The American Society of Refrigerating Engineers will have papers of interest to *Power* readers at its meeting in Cleveland, May 27-29, as follows: "Fluids with Reference to Their Adaptability for Both Positive and Centrifugal Compression," by W. H. Carrier and R. W. Waterfill, of the Carrier Engineering Corp.; "Power Lubrication," by Charles H. Bromley, S. F. Bowser & Co., Inc.; "The Flywheel Problem in Compressors Direct Connected to Synchronous Motors," by A. R. Stevenson, Jr., General Electric Co.; "Heat Transfer in Cast-Iron Radiators for Ammonia," by H. J. Macintire, University of Illinois; "Temperature Measurements in Installation Testing," and "An Analysis with Special Reference to Future Investigations," by Percy Nicholls, A. S. H. & V. E. Experiment Station, Pittsburgh, Pa.

Society Affairs

The Providence Engineering Society will hold a power session on May 16. "Oil Burning" will be the subject of the evening, and Ernest H. Peabody will be the speaker.

The New York Sections of the American Welding Society will have "Welding Manganese Steel" as the topic for its May 13 meeting. C. W. Miller will be the speaker.

The Detroit Engineering Society will have as the speaker of its May 16 meeting, H. H. Thrall, supervisor of inspectors, Department of Labor and Industry. He will speak on "The Engineer's Part in Safety Work."

The Hartford Engineers Club will hold its first annual dinner and meeting on May 14, at the Hotel Garde, Hartford. F. G. Hughes, vice-president of the New Departure Manufacturing Co., will be the speaker.

The Industrial Preparedness Meeting, a feature of the spring meeting of the A.S.M.E. at Cleveland, Ohio, May 26-29, will take place on Wednesday evening, May 28. Bernard Baruch, Newton D. Baker and Assistant Secretary of War Dwight F. Davis will be the speakers.

The National Board of Boiler and Pressure Vessel Inspectors will be addressed by Fred R. Low, president of the A.S.M.E., at the meeting which is to be held at the same time in Cleveland, as the A.S.M.E. spring meeting. Mr. Low will speak on "The Necessity of Uniform Enforcement of the Boiler Code and Interpretations."

Stokers Sold During First Three Months of 1924

(According to the Department of Commerce.)

Month 1924	Establishments Reporting (Number)	Stokers Sold		Installed under Fire-tube Boilers		Installed under Water-tube Boilers	
		Number	Horsepower	Number	Sq.ft. of Heating Surface	Number	Sq.ft. of Heating Surface
January	15	91	66,492	7	10,440	84	654,480
February	15	110	62,113	11	15,250	99	605,880
March	15	89	34,597	12	16,250	77	329,720

The Boston Section of the A.S.M.E. will hold a joint meeting with the Tufts College Student Branch on May 15. I. E. Moultrop will speak on "The New Edison Station at Weymouth, Mass."

The Providence Engineering Society will have, as the attraction for its May 13 meeting, a talk on "Engineering a Changing Art," by F. C. Wight of the *Engineering News-Record.*

The Chicago Section of the A.S.M.E. will hold a dinner meeting at the Hamilton Club on May 20, to which the ladies are invited. "Engineering Education" is to be the subject of the meeting.

The Engineering Society of Western Massachusetts will hold its annual meeting on May 20 at Hotel Kimball, Springfield, Mass. Guy E. Tripp, of the Westinghouse Elec. & Mfg. Co., and Willard Scott will be the principal speakers.

The Boston Society of Civil Engineers will have "Muscle Shoals Project with Special Emphasis on the Wilson Dam," (illustrated) as the subject for its May 14 meeting, Major Stuart C. Godfrey, engineer officer, First Corps, Area, will be the speaker.

The A.S.M.E. Subcommittee on Standardization of Ammonia Fittings will consider standards for flanged and screw fittings to be used in the installation of ice making and refrigeration at its meeting on May 14, at 29 West 39th St., New York City.

The Boston Plant Engineers' Club will visit, on the afternoon of May 21, the Worthington Pump & Machinery Corp. plant to inspect a new diesel engine under construction there. George E. Freethy will talk at the evening dinner meeting, on "Pumps and Their Special Application."

The A.S.M.E. recently, desiring to increase its yearly dues for members, associates and associate-members from $15 to $20, sent out blanks for voting on the question to its membership. The result of the vote shows that a substantial majority are in favor of the increase.

The Detroit Engineering Society held its annual meeting and banquet on April 26. The following officers were elected for the year 1924-25: Frank Burton, president; George H. Fenkell, first vice-president; G. R. Thompson, second vice-president; Fred A. Compton, secretary-treasurer; L. E. Williams to executive committee.

The Boiler Code Committee of the A.S.M.E. will hold its May meeting at Hotel Cleveland, Cleveland, Ohio, in connection with the spring meeting of the A.S.M.E., on the morning of May 27. One of the objects of holding the meeting at this time and place is that it will enable the members to participate in the meetings of and co-operate with the National Board of Boiler Pressure Vessel Inspectors, who will be assembled in Cleveland in annual meeting at this time. The members of the National Board are being extended a cordial invitation to attend the meetings of the Code Committee.

Coming Conventions

American Association of Engineers. C. E. Drayer, 63 East Adams St., Chicago, Ill. Annual meeting at San Francisco, June 11-13.

American Boiler Manufacturers' Association. H. N. Covell, 191 Dikeman St., Brooklyn, N. Y. Annual meeting at the "Homestead," Hot Springs, Va. June 9-11.

American Order of Steam Engineers. W. S. Wetzler, 753 North 44th St., Philadelphia, Pa. Annual meeting at Moose Hall, 1314 North Broad St., Philadelphia, Pa., June 9-13.

American Society of Heating and Ventilating Engineers, F. C. Houghten, 29 West 39th St., New York City. Semi-annual meeting at Kansas City, Mo., June 10-12.

American Society of Mechanical Engineers, Calvin W. Rice, 29 West 39th St., New York City. Spring meeting at Cleveland, Ohio, May 26-29.

American Society of Refrigerating Engineers, W. H. Ross, 35 Warren St., New York City. Annual meeting at Cleveland, Ohio, May 27-29.

American Water Works Association. J. M. Diven, 153 West 71st St., New York City. Annual convention at New York City, May 19-21.

Canadian Association of Sationary Engineers. Gordon C. Keith, 51 Wellington St., West Toronto, Ont. Annual meeting, St. Thomas, Ont., June 24-26.

Electric Power Club. S. N. Clarkson, Keith Bldg., Cleveland, Ohio. Meeting at Seaview Golf Club, Absecon, N. J., May 26-29.

International Railway Fuel Association. J. B. Hutchinson, 6000 Michigan Ave., Chicago. Annual convention at Hotel Sherman, Chicago, Ill., May 26-29.

Master Boiler Makers Association. H. D. Vought, 26 Cortlandt St., New York City. Meeting at Chicago, May 20-23, 1924.

National Association of Stationary Engineers. Fred W. Raven, 417 South Dearborn St., Chicago, Ill. Annual convention and exhibition at Hotel Pantlind, Grand Rapids, Mich., Sept. 8-13. Annual conventions and exhibitions of the state associations are scheduled as follows: **Illinois Association** at Rockford, Ill., June 4-6. L. G. Schlemm, 805½ South Ninth St., Springfield, Ill. **New Jersey Association** at Newark, June 6-8. Joseph P. Flynn, 612 Franklin St., Elizabeth, N. J. **Iowa Association** at Sioux City, June 10-14. Abner Davis, 16 Waterhouse Block, Cedar Rapids, Iowa. **New York State** at Niagara Falls, June 13-14. William Adelyotte, Shredded Wheat Co., Niagara Falls. **Ohio Association** at Akron, June 19-21. T. S. Garrett, 2622 East Second St., Dayton, Ohio. **Connecticut Association** at Bridgeport. June 27-28. George F. Klopfer, 30 East Pearl St., New Haven, Conn.

National Board of Boiler and Pressure Vessel Inspectors, C. O. Myers, 502 Comstock Bldg., Columbus, Ohio. Annual meeting at Cleveland Hotel, Cleveland. Ohio, May 26-29.

National District Heating Association, D. L. Gaskill, 112 West Fourth St., Greenville, Ohio. Annual convention at New York City, June 10-12.

National Electric Light Association. M. H. Aylesworth, 29 West 39th St. New York City. Annual convention at Atlantic City, Young's Million-Dollar Pier, May 19-24.

National Fire Protection Association. F. H. Wentworth, 40 Central St., Boston, Mass. Annual meeting, Atlantic City, N. J., May 13-15.

Smoke Prevention Association. Frank A. Chambers, 111 North Dearborn St., Chicago, Ill. Eighteenth annual convention at Hotel Statler, Buffalo, N. Y., June 3-5.

Stoker Manufacturers Association. G. A. Sacchi, Westinghouse Elec. & Manufacturing Co., Philadelphia, Pa. Annual meeting at Edgewater Beach Hotel, Chicago, Ill., June 2-4.

World Power Conference. O. C. Merrill, Federal Power Commission, Washington, D. C. British Empire Exhibition, Wembley, London, June 30-July 12.

Personal Mention

Freyn, Brassert & Co., engineers, will after May 1, be located in the Straus Bldg., 310 South Michigan Ave., Chicago, Ill.

R. B. Williamson, of the Allis-Chalmers Mfg. Co. sailed April 26 for a two months' trip to the British Isles and Europe. During this trip he will attend the British Empire Exposition at Wembley and inspect various European engineering developments.

Barzillai Allen Rich, William Walter Bigelow and **Charles Edwards Tirrell** have formed a partnership under the name of Rich, Bigelow & Tirrell, with offices at 333 Washington Street, Boston, Mass., for the practice of civil, mechanical and power development engineering, continuing the business formerly carried on by Stone, Bigelow & Tirrell at Boston.

Business Notes

The Flexo Supply Co., St. Louis, Mo., is moving its place of business, on May 10, from 201 Merchants Exchange Bldg. to 104 South Main St.

The Kuhlman Electric Co., Bay City, Mich., manufacturer of transformers, has opened a sales offices at 300 Madison Ave., New York City under the management of D. F. Potter, Jr.

The Public Service Production Co., 80 Park Place, Newark, N. J., affiliated with the Public Service Corp., has recently acquired the services of H. O. Pond in the capacity of sales engineer.

The Blaw-Knox Co., Pittsburgh, Pa., announces that Irving A. Pfeil, of the Chicago office has been appointed manager of the company's Detroit branch succeeding Herbert J. Desson, who died on April 16.

The Pennsylvania Pump & Compressor Co., Easton, Pa., has appointed the Pneumatic Equipment Co., George S. Githins, as its district representative for New England with offices at 110 High St., Boston, Mass.

The Industrial Works, Bay City, Mich., announces that L. A. Marshall, who has been connected with the company for many years is now sales engineer connected with its Chicago office, at 1051 McCormick Bldg.

The Bristol Company, Waterbury, Conn., manufacturers of recording instruments, announces the opening of a new Midwest service station at 3617 South Ashland Ave., Chicago, Ill. This station will be devoted to the repairing and recalibrating of instruments sold and used in the Midwest territory. The salesroom and offices will be maintained in the Monadnock Building.

Refrigerating Machinery Information Wanted—According to government reports the American Consul, George F. Dickins, Penang Straits Settlement, has requested, on account of an inquiry from the Siamese Consulate in Penang, that firms interested send him catalogs and descriptive matter on medium-sized ice-making machinery plants and other information on refrigeration.

Trade Catalogs

Gage, Level—The Foxboro Co., Inc., Foxboro, Mass. Leaflet describing liquid level gage.

Electric Measuring Instruments—Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. Catalog No. 75, "Apparatus for Electrometric Determination of Hydrogen Ion Concentration," contains, besides general considerations, working formulas and practical considerations in applying the working formulas, a bibliography of representative papers on the subject of hydrogen ion concentrations. Price lists of pententiometers, galvanometers, galvanometer reading devices and accessories, electrodes and accessories and other apparatus made by the company are included.

Insulation of High-Temperature Equipment—Celite Products Co., Chicago, Ill. This pamphlet contains the complete text and illustrations of a lecture that the Celite Products Co. is giving at approximately fifty of the large universities during the present school year. It shows curves of conductivities of various materials, charts of heat loss through various wall constructions and heated equipment, photographs of insulated equipment under construction, etc. While prepared primarily for distribution at the lecture, these printed copies are also available for general distribution. Schedule is now being arranged for delivery of the lecture during the 1924-25 school year.

Fuel Prices

BITUMINOUS COAL

The following table shows the trend of the spot steam market in various coals (mine run bases, f.o.b. mines):

Coal	Market Quoting	Apr. 28, 1924	May 5, 1924
Pool 1	New York	$3.00	$3.00
Smokeless	Columbus	2.35	2.35
Clearfield	Boston	2.35	2.40
Somerset	Boston	2.50	2.65
Kanawha	Columbus	....	....
Hocking	Columbus	1.75	1.75
Pittsburgh No. 8	Cleveland	1.85	1.90
Franklin, Ill.	Chicago	2.50	2.50
Central, Ill.	Chicago	2.25	2.25
Ind. 4th Vein	Chicago	2.50	2.50
West Ky.	Louisville	1.75	1.75
S. E. Ky.	Louisville	1.75	1.75
Big Seam	Birmingham	2.25	2.25

FUEL OIL

New York—May 8, light oil, tank-car lots, 28@34 deg., Baumé, 5½c. per gal., 36@40 deg. 6c. per gal., f.o.b. Bayonne, N. J.

St Louis—May 2, tank-car lots, f.o.b. St. Louis; 24@26 deg., $1.75 per bbl.; 26@28 deg., $1.80 per bbl.; 28@30 deg., $1.85 per bbl.; 32@36 deg., gas oil, 5⅝c. per gal.; 38@40 deg., 6c. per gal.

Pittsburgh—May 1, f.o.b. local refinery, 30@34 deg., fuel oil, 5¼c. per gal.; 36@40 deg., fuel oil, 5¾c. per gal.; 34 deg., neutral, 8¼c. per gal.

Dallas—May 2, f.o.b. local refinery, 26@30 deg, $1.30@$1.35 per bbl.

Philadelphia—May 2, 28@30 deg., $2.415@$2.478 per bbl.; 18@22 deg., $2.10@$2.16½; 13@16 deg., $1.785@$1.848 per bbl.

Boston—May 6, tank-car lots, f.o.b. heavy oil, 12@14 deg. Baumé, 4⅝c. per gal., light oil, 28@32 deg., Baumé, 6⅝c. per gal.

Cincinnati—May 6, tank-car lots, f.o.b. local refinery, 24@26 deg. Baumé, 5¼c. per gal.; 26@30 deg., 5¾c. per gal.; 30@32 deg., 6c. per gal.

New Plant Construction

Ala., Ariton—The National Lumber Co., recently organized, plans for a power plant at its proposed mill. O. S. Ranier, president.

Ala., Cordova—The Cooper Ice Co., recently organized, plans for an ice-manufacturing plant. I. E. Cooper heads the company.

Ala., Sulligent—The Henson Gravel Co., Columbus, Miss., recently organized, is considering the installation of pumping equipment, for water service. D. C. Nickles, secretary.

Ariz., Phoenix—The Salt River Valley Water Users' Assoc. plans a 35,000 hp. hydro-electric plant at the Horse Mesa Dam, estimated cost $4,000,000, with transmission system. C. C. Cragin is general superintendent.

Ark., Pine Bluff—The Arkansas Light & Power Co. is selling bonds for $1,650,000, part to be used for extensions and improvements, including the completion of the first unit of a 15,000 hp. hydro-electric power station on the Ouachita River. Other units will be constructed later.

Ark., Gassville—The White River Canning Co. is considering a boiler plant at its canning factories on local site and Flippen, Ark., to cost $75,000. H. E. Harmon, president.

Ark., Mena—The electric light and power plant, and ice-manufacturing plant of the Commonwealth Public Service Co. has been acquired by W. F. Moody and G. O. Macfarlane, Little Rock, Ark., and associates. The new owners are considering extensions and improvements.

Ariz., Mesa—The Independent Cotton & Oil Co., El Paso, Tex., Will T. Owens, president, plans for a power plant at its cottonseed oil mill, estimated to cost $350,000.

Calif., Beaumont—The Beaumont Fruit Growers' Association has plans for an ice and cold storage plant at Fifth and Veilie Sts., to cost $100,000.

Calif., El Centro—Bonds for $200,000 have been approved for extension of municipal waterworks, including electric-operated pumping equipment and other machinery. Bids will soon be asked by the City Council.

Calif., Martinez—The Alunite Potash Co. plans for a steam power house at its plant on 7-acre tract of land, estimated to cost $75,000.

Calif., Oakdale—The Board of City Trustees plans for a pump for the municipal waterworks, capacity of 600 gal. per min.

Calif., San Bernardino—The City Council plans for electric-operated pumping equipment for extensions in municipal waterworks for new supply from Devil Canyon. Bonds for $275,000, have been approved.

Calif., Whittier—The Board of City Trustees plans electric-operated pumping equipment in connection with proposed extensions to the municipal waterworks, estimated cost $100,000. C. O. Trueblood is city clerk.

Colo., Loneland—The city has been authorized by its councilmanic body to issue $425,000 Loveland Municipal Light and Power Revenue Bonds and the city has authorized Hendrie and Bolthoff of Denver to go ahead with the erection of the plant. The Hendrie concern bid was $371,685.14.

Conn., Bridgeport—The Bridgeport Hydraulic Co. operating waterworks properties, plans extensions, including electric-operated pumping equipment. Bonds for $5,000,000 are being sold. Part of this to be used for expansion. Samuel P. Senior is president.

Conn., Danbury—The McLachlan Hat Mfg. Co. plans for a power plant at its factory to cost $55,000. Bids to be asked during month. The Fletcher-Thompson Co., 542 Fairfield Ave., Bridgeport, Conn., engineer.

D. C., Washington—The Bureau of Supplies and Accounts, Navy Department, will take bids until May 20, for flexible metallic hose for eastern and western yards, as per Schedule 2141.

Fla., Pensacola—The Pure Oil Co., Pure Oil Bldg., Columbus, Ohio, plans for electric-operated pumping equipment at its terminal and distributing plant, to cost $350,000.

Fla., Stuart—The Inlet Power & Ice Co., recently formed with a capital of $100,000, plans for a new ice-manufacturing plant. F. A. Parsons, president.

Fla., Tampa—The United States Export Chemical Co., 476 First Ave., North, St. Petersburg, Fla., plans for a power station at its phosphate works, to cost $250,000. Work will soon begin.

Fla., Vero—The Harris-Cobb Co., recently formed with C. E. Cobb, president, is considering a boiler plant at its citrus fruit packing works, to cost $40,000.

Ga., Atlanta—The Georgia Railway & Power Co. will proceed with the construction of its proposed power dam at Yonah Falls, to be 75 ft. high and 900 ft. long, with hydro-electric power plant of 25,000 kw. capacity.

Ill., Canton—The supervising architect, Treasury Department, Washington, D. C., will receive bids until May 22, for one horizontal smokeless firebox boiler, arranged for portable setting, for the post office.

Ind., Anderson—The Hughes-Curry Packing Co., 2000 West Eighth St., plans for a cooler and refrigerating building, at its new packing house, 2300 West Eighth St. The first structure will cost $100,000, with equipment. The entire plant estimated to cost $200,000. Charles Hughes, president and general manager.

Ind., Aurora—The United States Engineers, Cincinnati, Ohio, will commence the immediate erection of a power house on the Ohio River, Dam No. 38, near Aurora.

Ky., Mayfield—The City Council plans for the installation of electric-operated pumping equipment in connection with its proposed sewerage plant and system, for which plans are being prepared by Black & Veatch, Mutual Bldg., Kansas City, Mo., engineers.

Ky., Paintsville—The City Council will soon take bids, to be opened July 1, for equipment for its municipal waterworks, including two pumping engines, electric-operated or gas-driven, and accessory apparatus, and one 250,000 gal. steel tank, to cost $70,000. The J. N. Chester Engineers, Union Bank Bldg., Pittsburgh, Pa., are preparing plans and specications.

La., Breaux Bridge—Collins Conrad, Lafayette, La., and associates, are forming a company to construct and operate an electric plant, with ice-manufacturing adjoining, to cost $80,000.

La., New Iberia—Lawrence F. Villermin, city clerk, will receive bids until May 20, for equipment for the municipal electric plant and waterworks, including two 275 kw. a.c. generators, direct-connected to Diesel oil engines; two 1,000 gal. per min. centrifugal pumps for fire service; one 600 gal. per min. centrifugal pump; one 1,000 gal. per min. centrifugal pump, all pumping units to be motor-driven; switchboard

and auxiliary apparatus. J. W. Billingsley, Interstate Bank Bldg., New Orleans, La., is engineer.

La., Oak Grove—The Common Council has arranged a special election to vote bonds for $45,000, for a municipal electric plant and waterworks installation. Henry A. Menz, Magnolia, Miss., is engineer.

Md., Annapolis—The local Navy Supply Officer, United States Navy Department, will take bids at once for two 5 hp. synchronous motors, as per Naval Requisition 479.

Md., Baltimore — The Board of Works plans and will soon call for bids for a municipal heating plant for the City Hall, Courthouse and other buildings, estimated to cost $250,000, with equipment. Steuart Purcell, City Hall, is city engineer; William F. Stone, Jr., Munsey Building, is architect.

Md., Elkton — The Maryland Tool Co. plans rebuilding part of its boiler plant recently destroyed by fire.

Md., Westminster—The Zile-Neuman Co., 207 East Main St., recently organized with capital of $100,000, for an ice cream plant, has plans for an ice-manufacturing plant, with capacity of 25 tons per day. Edward W. Neuman, president.

Mass., Norton—The Board of Trustees, Wheat College, S. V. Cole, president, plans for a steam power plant at the institution. Bids will be asked for soon. Cram & Ferguson, 248 Boylston St., Boston, architects.

Mich., Albion — The Michigan Artificial Ice Products Co., Detroit, plans for a new ice-manufacturing and cold storage plant with initial capacity of 20 tons per day. Estimated cost $85,000, with equipment.

Mich., Calumet—The Calumet & Hecla Co., operating copper properties, has authorized pulverized fuel burning equipment for a number of local furnaces.

Minn., Aitkin — The Prairie River Power Co. has made application to construct and operate a hydro-electric plant at Ox Bow Rapids, near Aitkin. Initial capacity, 6,000 hp.

Minn., Duluth—The Dominion Tar & Chemical Co., 5910 Fremont St., will build a one-story boiler plant, 30 x 42 ft., at its proposed new manufacturing works on Sixtieth St., estimated to cost $45,000. Work will begin at an early date.

Minn., Luverne — The Common Council will take bids until June 3, for equipment for new unit at the municipal electric plant, including engine, 350-kw. generator, and auxiliary apparatus. C. W. Campbell, city recorder in charge.

Minn., Red Wing — The Cannon River Hydro-Electric Co. plans for a hydro-electric plant on the Cannon River, estimated to cost $200,000.

Minn., Waconia — The Common Council plans for electric-operated pumping equipment in connection with extensions in muncipal waterworks. Bond issue of $25,000, is being arranged.

Miss., Jackson — The American Box & Lumber Co., recently organized, plans for a boiler plant, at its mill. G. W. Newton, Bristol, Va.-Tenn., architect. C. V. Myers, secretary.

Miss., Meridian — The Common Council has authorized immediate extensions in the pumping station at the municipal waterworks, including additional equipment.

Mo., St. Louis — The United States Indian warehouse will take bids until May 29, for annual supplies, including rubber and leather belting, blowers, gaskets, gauge glasses and miscellaneous items as per list, Class 17.

Mo., Nevada—The supervising architect, Treasury Department, Washington, D. C., will take bids until May 19, for removing present boiler and installing new heating boiler at the post office.

Mo., St. Joseph—The City Council plans for extensions and improvements in municipal electric power plant, including two boilers, engine, generator and accessory equipment. Purposed to ask bids soon. The expansion to cost $50,000.

Mo., Steele—The Common Council plans for electric-operated pumping equipment at waterworks plant. Bonds for $60,000 are being arranged.

Neb., Fremont — The supervising architect, Treasury Department, Washington, D. C., will receive bids until May 20, for removing present boiler and installing new heating boiler at the post office.

Neb., Ulysses — The Common Council plans for electric-operated pumping equipment in waterworks extensions. Bond issue being arranged.

Nev., Reno—The supervising architect, Treasury Department, Washington, D. C., will take bids until May 23, for new oil-burning apparatus, storage tank, etc., for the post office.

N. H., Portsmouth—The local Navy Supply Officer, United States Navy Department, will take bids at once for 9 air powered submerged pumps, as specified in N. S. A. requisition 479.

N. Y., Ballston Spa — The Board of Saratoga County Supervisors will soon take bids for a hydro-electric plant for service at the Homestead Sanatorium. The Utilities Engineering Co., 467 Broadway, Albany, N. Y., is engineer.

N. Y., Cortland—The City Council contemplates electric-operated pumping equipment in proposed extensions and improvements in the waterworks, to cost $55,000.

N. Y., Jamestown—The Board of Public Welfare plans for electric-operated pumping equipment at sewerage disposal works, to cost $170,000. Bids will soon be called.

N. Y., New York—The local Navy Supply Officer, United States Navy Department, South and Whitehall Sts., will take bids at once for 500-boiler tube brushes, as per N. S. A. requisition 900.

N. Y., Wolcott — The Commercial Packers' Association, North Rose, N. Y., plans for a refrigerating plant at packing house, to cost $160,000, with equipment.

N. C., Asheville—The Beacon Mfg. Co., New Bedford, Mass., plans for a boiler plant at its cotton mill. Construction will begin in June. W. R. Campbell, Asheville, local representative.

N. C., Canton—The Canton Electric Co., recently acquired by new interests, is said to have plans under way for a hydro-electric plant on the Pigeon River in Haywood County.

N. C., Fayetteville — The supervising architect, Treasury Department, Washington, D. C., will take bids until May 27, for the installation of one new horizontal smokeless firebox heating boiler, arranged for portable setting, at the post office, and the removal of present boiler.

N. D., Grand Forks—The State Board of Administration, Bismarck, N. D., plans for additional equipment at the electric power plant at the state university, including engine, generator, pumps, and accessory apparatus. Bids will soon be asked.

N. C., Charlotte—The Board of City Commissioners contemplates the installation of electric-operated pumping equipment in connection with proposed waterworks extensions to cost $250,000, in which amount bonds are being arranged. A new septic tank will be installed to cost $50,000.

N. C., Greensboro — The Board of Trustees, North Carolina College for Women, will immediately erect a power plant at the institution, to cost $45,000.

N. C., Lawndale—The Cleveland Mill & Power Co. plans and will soon award contracts for a hydro-electric plant on the First Broad River. A list of equipment to be installed, including water trubines, generators and auxiliary equipment has been prepared. Mees & Mees, Charlotte, N. C., are engineers.

N. C., Oxford—C. D. Ray & Son plan rebuilding the portion of their lumber mill and boiler plant, destroyed by fire, April 27, with $30,000 loss.

N. C., Weldon—Bids will be received by the Town Clerk until May 21, for extensions and improvements in the municipal waterworks, including motor-driven centrifugal pumps and accessory apparatus; steel water tank and tower, as per plans and specifications on file at the office of the Gilbert C. White Co., Durham, N. C., engineer.

N. C., Winston-Salem — The Zinzendorf Laundry Co. will build a steam electric plant at its new laundry on South Main St. near Walnut St., to cost $100,000. Harold Macklin, Winston-Salem, is architect.

Ohio, Junction City—The Great Western Sewer Pipe Co. plans for a boiler plant at its factory, to cost $75,000.

Okla., Cushing — The Deer Creek Pipe Line Co. plans for pumping plants in connection with its 35-mile pipe line for crude oil service, to cost $300,00. R. C. Jones is head.

Okla., Frederick—The City Council plans a special election to vote bonds for $75,000, for extensions and improvements in the municipal electric power plant, with additional equipment.

Okla., Tulsa—The supervising architect, Treasury Department, Washington, D. C., will take bids until May 26, for oil-burning equipment for use at the power house of the post office and court house.

Pa., Altoona—The Pennsylvania Railroad Co., Broad St. Station, Philadelphia, Pa., will build a boiler plant at its shops to cost $50,000. Contract for building has been let to the Columbia Construction Co., Altoona.

Pa., Lewistown — The Borough Council plans for electric-operated pumping equipment at the sewerage disposal works, to cost $400,000. Banks & Craig, Telegraph Bldg., Harrisburg, Pa., engineers.

Pa., Philadelphia — The Navy Supply Officer, United States Navy Department, will take bids at once for 9 relief valves and 9 pressure valves, per N. S. A. requisition 789.

S. C., Winnsboro—The Fairfield County Granite Co. plans to purchase a steam or crude oil engine, about 100 hp. capacity, with accessory apparatus.

Tenn., Bristol—The Common Council is considering electric-operated pumping equipment for proposed extensions in the waterworks. A bond issue of $35,000, is being arranged.

Tex., Floydada—T. H. Harris, Sulphur Springs, Tex., plans for a boiler plant at his cotton ginning works. Site has been selected.

Tenn., Grand Saline—The Common Council plans for electric-operated pumping equipment at the municipal waterworks. Bonds for $50,000 are being arranged.

Tenn., Morristown — A special election called on May 15 to vote bonds for $300,000, for extensions and improvements in the waterworks, including pumping machinery and auxiliary equipment, and enlargement in the municipal electric power plant, including additional equipment. Plans soon to be prepared.

Tex., Hico—The Hico Ice & Cold Storage Co. plans for a new ice-manufacturing and cold storage plant at Glen Rose.

Tex., Terrell—The City Commission will make extensions in the municipal electric power plant, with additional equipment to double the present capacity.

Tex., Winters—The Common Council is considering electric-operated pumping equipment for the sewerage works. Bonds for $50,000, have been approved.

Va., Altavista—W. S. Corbin, chairman of water committee, will receive bids until May 19, for equipment for pumping plant at the waterworks, including two high-service centrifugal pumps, each with capacity of 350 gal. per min., motor-driven; two low-service centrifugal pumps, same capacity, motor-driven; one semi-Diesel oil engine, 45 hp. capacity; 30,000-gal. capacity steel tank on tower. The Ambler Engineering Co., Richmond, Va., engineer.

Va., Hampton Roads—The local Navy Supply Officer, United States Navy Department, will take bids at once for 500 boiler-tube brushes, as per N. S. A. requisition 594, for use at the naval operating base.

Va., Hopewell — The Dixie Decorating Co., recently organized, plans for a boiler house at its pottery, to cost $55,000. F. F. Nickell is president.

Va., Portsmouth—The Common Council plans for an electric-operated pumping equipment for extensions in waterworks. Bond issue of $25,000, is being arranged.

W. Va., Grafton—The Common Council is considering electric-operated pumping equipment for extensions in the municipal waterworks, to cost $125,000.

W. Va., Hopemont—The State Board of Control, Charleston, W. Va., will construct a steam-electric plant at the state tuberculosis sanitorium, to cost $50,000.

W. Va., Huntington—The Philadelphia & Cleveland Coal Co. plans for coal-handling and conveying machinery at its proposed coal-loading dock. Graham, Scott & Wiswell, First National Bank Bldg., Huntington, are engineers in charge.

W. Va., Rivesville—The Common Council is considering electric-operated pumping machinery for proposed waterworks system, to cost $41,000. S. B. Miller, Fairmount, W. Va., is engineer.

W. Va., Salem—The City Council plans for electric-operated pumping equipment with accessory apparatus for extensions and improvements in municipal waterworks. Bonds for $75,000, have been voted.

Wis., Milwaukee—The Pittsburgh Plate Glass Co., Frick Bldg., Pittsburgh, Pa., has work in progress on a new power plant at its paint and varnish works to cost about $350,000. Building ready for equipment at an early date.

PRICES - MATERIALS - SUPPLIES

Electrical prices on following page are prices to the power plant by jobbers in the larger buying centers east of the Mississippi. Elsewhere the prices will be modified by increased freight charges and by local conditions.

SINCE LAST MONTH

Power plant and electrical supplies fairly firm at present levels; prices show little change from those in effect one year ago. Market normal for heavy electrical equipment and materials. With the exception of boiler rivets all price changes were in a downward direction. The declines occurred in steel shapes, wiping cloths, chrome brick and cement, silica brick, armored cable and rubber covered copper wire.

POWER-PLANT SUPPLIES

HOSE—

Fire	50-Ft. Lengths
Underwriters' 2½-in., coupled	61c. per ft.
Common, 2½-in., 3-ply — $1.00 per ft. list less	40%

Air—Best grade

¾-in., per ft.	3-ply $0 36	4 ply $0.44½

Steam—Discounts from List

First grade 30%	Second grade 40%	Third grade 40-5%

RUBBER BELTING—The following discounts from list apply to transmission rubber and duck belting:

Best grade 50%	Second grade 50-5%

LEATHER BELTING—List price, 2c. per sq. in., per ply.

Grade	Discount from list
Medium	40-2½%
Heavy	30-5%

RAWHIDE LACING { For cut, best grade, 45-5%, 2nd grade, 55%. For laces in sides, best, 41c. per sq.ft.; 2nd, 37c. Semi-tanned: cut, 45-5%; sides, 41c. per sq.ft.

PACKING—Prices per pound:

Rubber and duck for low-pressure steam, ½ in.	$0.90
Asbestos for high-pressure steam, ¼ in.	1.70
Duck and rubber for piston packing	.90
Flax, regular	1.10
Flax, waterproofed	1.70
Compressed asbestos sheet	.80
Wire insertion asbestos sheet	1.30
Rubber sheet	.45
Rubber sheet, wire insertion	.70
Rubber sheet, duck insertion	.50
Rubber sheet, cloth insertion	.25
Asbestos packing, twisted or braided and graphited, for valve stems and stuffing boxes	1.30
Asbestos wick, ½- and 1-lb. balls	.50

PIPE AND BOILER COVERING—Discounts, New York warehouses, are as follows:

85% magnesia high pressure		50%
For low-pressure heating and return lines	4-ply	70%
	3-ply	72%
	2-ply	74%

PORTLAND CEMENT—New York, $2.50@ $2.60 per bbl. without bags, in carload lots delivered on job. Bag charge of 40c. per bbl.

STRUCTURAL STEEL—New York delivered price, 3 to 15-in. beams and channels and 3 to 6-in. angles, tees, and plates, all $3.59 per 100 lb.

COTTON WASTE—The following prices are in cents per pound:

	New York	Cleveland	Chicago
White	14@21	20.00	14.00
Colored	9@12.50	17.00	10.50

WIPING CLOTHS—Jobbers' prices, in cents per lb., as follows:

	13½ x 13½	13½ x 20½
Chicago	16.00	16.00
New York	11.50	
Cleveland	$36.00 per M.	$52.00 per M.

LINSEED OIL—These prices are per gallon:

	New York	Cleveland	Chicago
Raw in barrels (5 bbl. lots)	$0.95	$1.08	$0.94

WHITE AND RED LEAD—In 100-lb. kegs, base price in cents per pound:

	Dry		In Oil	
	Current	1 Yr. Ago	Current	1 Yr. Ago
Red	15.00	14.25	16.50	15.75
White	15.00	14.25	15.00	14.25

RIVETS—The following quotations are allowed for fair-sized orders from warehouse:

	New York	Cleveland	Chicago
Steel ⅛ and smaller	50%	60%	60%
Tinned	50%	60%	4½c. per lb. net

Structural rivets, ½ , ⅝, 1 in. diameter by 2 in. to 5 in. sell as follows per 100 lb.

New York	$4.40	Chicago	$3.75	Pittsburgh	$2.65@$2.75

Boiler rivets, same sizes:

New York	$4.50	Chicago	$3.85	Pittsburgh	$3.15@$3.25

REFRACTORIES—Prices in carlots f.o.b. plant:

Chrome brick, eastern shipping points	net ton	$47@52
Chrome cement, 40@ 50% Cr_2O_3, in bulk	net ton	22@27
Chrome cement, 40@ 50% Cr_2O_3, in sacks	net ton	26@31
Magnesite brick: 9-in. straights	net ton	65@68
Magnesite brick: 9-in. arches, wedges and keys	net ton	71.50@74.80
Magnesite brick: Soaps and spits	per ton	91.00@95.20
Silica brick: Mt. Union, Pa.	per M	38@40
Clay brick, 1st quality, 9 in. shapes, Pennsylvania	per M	41@48
Clay brick, 1st quality, 9 in. shapes, Ohio	per M	42@43
Clay brick, 1st quality, 9 in. shapes, Kentucky	per M	42@43
Clay brick, 2nd quality, 9 in. shapes, Pennsylvania	per M	36@43
Clay brick, 2nd quality, 9 in. shapes, Ohio	per M	37@39
Clay brick, 2nd quality, 9 in. shapes, Kentucky	per M	37@39
Chrome ore crude, 40@50%	net ton	17.00@19.50

BABBITT METAL—Warehouse prices in cents per pound:

	New York	Cleveland	Chicago
(83% tin)	60.00	61.00	48@52
(35% tin)	28.00	19.50	23@26

COLD DRAWN STEEL—Warehouse prices are as follows:

	New York	Cleveland	Chicago
Round shafting and screw stock, per 100 lb. base	$4.40	$4.10	$4.00
Flats, square and hexagons, per 100 lb. base	4.90	4.60	4.50

BOILER SPECIALTIES—F. o. b. New York or Jersey City, discounts on list:

	Current
Copper ferrules	70%
Boiler flanges	60-10%
Boiler stay bolts	60%
Boiler patch bolts	10%
Boiler fitting-up bolts	45%
Pressed steel boiler lugs	10%
Pressed steel boiler hangers	10%

WROUGHT PIPE—The following discounts are to jobbers for carload lots on the latest Pittsburgh basing card:

BUTT WELD

Inches	Steel Black	Steel Galv.	Inches	Iron Black	Iron Galv.
1 to 3	62	50½	1 to 1½	30	13

LAP WELD

2	55	43½	2	23	7
2½ to 6	59	47½	2½	26	11
7 and 8	56	43½	3 to 6	28	13
9 and 10	54	41½	7 to 12	26	11
11 and 12	53	40½			

BUTT WELD, EXTRA STRONG, PLAIN ENDS

1 to 1½	60	49½	1 to 1½	30	14
2 and 3	61	50½			

LAP WELD, EXTRA STRONG, PLAIN ENDS

2	53	42½	2	23	9
2½ to 4	57	46½	2½ to 4	29	15
4½ to 6	56	45½	4½ to 6	28	14
7 and 8	52	39½	7 and 8	21	7
9 and 10	45	32½	9 to 12	16	2
11 and 12	44	31½			

BOILER TUBES—Following are prices in New York warehouse of tubes manufactured according to specifications of the American Society of Mechanical Engineers:

Size	Lapweld Steel	C. C. Iron	Seamless Steel
4	.....	.....	$0.23
1½	.....	.....	.25
1½	.....	.....	.22
1¾	$0.26	$0.29	.23
1	.20	.25	.21
1¼	.23	.29	.23
1½	.24	.33	.28
2¼	.....	.....	.....
2	.30	.41	.32
2¼	.32	.47	.35
3¼	.34	.51	.37
2	43	.64	.47

Tubes 2½ in. diameter, or smaller, over 18 ft. long, 10 per cent extra.

These prices are net per lineal foot based on stock lengths. If cut to special lengths, billing will be based on the entire stock lengths.

In addition to the above, standard cutting charges are as follows:

1¼ in. to 2 in. diameter, 5c. per cut. 2½ in. diameter, 7c. per cut
2½ in. diameter, 6c. per cut. 3 in. diameter, 9c. per cut
3¼ in. to 4 in. diameter, 10c.

ELECTRICAL SUPPLIES

ARMORED CABLE—Price per 1,000 ft.—5 per cent 10 days.

B. & S. Size	Two Cond. M Ft.	Three Cond. M Ft.	Two Cond. Lead M Ft.	Three Cond. Lead M Ft.
No. 14 solid	$ 43.00 (net)	$ 65.00 (net)	$164.00	$210.00
No. 12 solid	135.00	170.00	225.00	265.00
No. 10 solid	185.00	235.00	275.00	325.00
No. 8 stranded	285.00	375.00	520.00	500.00
No. 6 stranded	400.00	500.00	560.00	.....

From the above lists discounts are:		Lead Covered
Less than coil lots	35%	20%
Coils to 1,000 ft.	45%	25%
1,000 to 5,000 ft.	50%	30%
5,000 ft. and over	55%	35%

CONDUIT, Price per 1,000 ft.; **ELBOWS AND COUPLINGS**, Per 100 pieces, f.o.b. New York, with 10-day discount of 5 per cent.

Size In.	Conduit Black Per M	Conduit Galvanized Per M	Elbows Black Per C	Elbows Galvanized Per C	Couplings Black Per C	Couplings Galvanized Per C
¼	$61.10	$66.16	$9.90	$11.03	$5.74	$6.16
¾	79.20	84.95	13.00	14.49	8.18	8.78
1	112.06	122.19	19.26	21.46	10.65	11.42
1¼	151.62	165.31	25.65	28.33	14.76	15.78
1½	181.28	197.67	34.19	37.77	18.23	19.47
2	248.90	265.94	62.70	69.24	24.29	25.97
2½	385.50	420.48	102.58	111.33	34.71	37.10
3	504.29	548.81	273.40	302.12	51.66	55.63
3½	633.86	688.65	604.03	667.15	69.41	74.19
4	772.62	838.59	697.06	770.99	86.76	92.73

CONDUIT BODIES AND FITTINGS—Black or galvanized.

	Less than $10 list	$10 list to $100	$100 list and over
Standard package	10%	20%	28%
Less than standard package	5%	10%	20%

CUT-OUTS—Following are net prices each in standard-package quantities:

CUT-OUTS, PLUG

S. P. M. L.	$0.12	D. P. D. B.	$0.31
D. P. M. L.	.16	T. P. S. B.	.35
T. P. M. L.	.27	T. P. D. B.	.47
D. P. S. B.	.16		

CUT-OUTS, N. E. C. FUSE

	0-30 Amp.	31-60 Amp.	60-100 Amp.
D. P. M. L.	$0.27	$0.70	$1.75
T. P. M. L.	.40	1.00	2.30
D. P. S. B.	.35	.87	.....
T. P. S. B.	.67	1.50	.....
D. P. D. B.	.65	1.75	.....
T. P. D. B.	1.12	3.00	.....
T. P. to D. P. D. B.	.75	2.10	.....

FLEXIBLE CORD—Price per 1,000 ft. in coils of 250 ft.:

No. 18 cotton reinforced heavy	$22.00
No. 16 cotton reinforced heavy	25.50
No. 18 cotton reinforced light	18.50
No. 16 cotton reinforced light	21.50
No. 18 cotton Canvasite cord	16.50
No. 16 cotton Canvasite cord	18.75

NATIONAL ELECTRIC CODE FUSES, NON-REFILLABLE—

250-Volt	Std. Pkg.	List	600-Volt	Std. Pkg.	List
3-amp. to 30-amp.	100	$0.15	3-amp. to 30-amp.	100	$0.30
35-amp. to 60-amp.	100	.30	35-amp. to 60-amp.	100	.60
61-amp. to 100-amp.	50	.90	65-amp. to 100-amp.	50	1.50
101-amp. to 200-amp.	25	2.00	110-amp. to 200-amp.	25	2.50
201-amp. to 400-amp.	25	3.60	225-amp. to 400-amp.	25	5.50
401-amp. to 600-amp.	10	5.50	450-amp. to 600-amp.	10	8.00

Discount: Less 1-5th standard package, 55%; 1-5th to standard package, 60%; standard package, 65%.

RENEWABLE FUSES, ENCLOSED—List price each:

Sizes	250-Volt List-Price	600-Volt List-Price	Std. Pkg. Quantity	Carton Quantity
1 to 30-amp.	$0 50	$1 10	100	10
35 to 60-amp.	1 00	1 25	100	10
65 to 100-amp.	2 00	3 00	50	5
110 to 200-amp.	4 00	5 00	25	5
225 to 400-amp.	7.50	11 00	25	1
450 to 600-amp.	11.00	16.00	10	1
450 to 600-amp.	11.00	16.00	10	1

REFILLS—

1 to 30	$0.30 ea.	$0.05	100	100
35 to 60	.05 ea.	.06	100	100
65 to 100	.10 ea.	.10	50	50
110 to 200	.15 ea.	.15	25	50
225 to 400	.30 ea.	.30	25	25
450 to 600	.60 ea.	.60	10	10

Discount Without Contract—Fuses:	
Broken carton	5%
Unbroken carton but less than std. pkg.	22½%
Std. pkg.	40%
Discount Without Contract—Renewals:	
Less than std. pkg.	Net list
Standard package	40%
Discount With Contract—Fuses:	
Broken cartons	10%
Unbroken cartons but less than standard package	26%
Standard package	42%
Discount With Contract—Renewals:	
Less standard package	Net list
Standard package	42%

FUSE PLUGS, MICA CAP—

0-30 ampere, standard package (500)	$2 70
0-30 ampere, less than standard package	3 00

LAMPS—Below are present quotations in less than standard package quantities:

Straight-Side Bulbs Mazda B— Watts	Plain	Frosted	No. in Package	Pear-Shaped Bulbs or Bowl Enameled Mazda C— Watts	Clear	Frosted	No. in Package
10	$0.30	$0.35	120	50	$0.45	$0.50	60
15	.30	.35	120	75	.50	.55	60
25	.30	.35	120	100	.60	.65	24
40	.30	.35	120	150	.75	.80	24
50	.30	.35	120	200	1.00	1.10	24
60	.35	.40	120	300	1.60	1.70	24
				500	2 35	2.50	12
				750	3.75	3.95	8
				1,000	4.00	4.25	8

Standard quantities are subject to discount of 10% from list. Annual contracts ranging from $75.00 to $300,000 net allow a discount of 15 to 40% from list.

PLUGS, ATTACHMENT—

	Each
Porcelain separable attachment plug	$0.18
Composition 2-piece attachment plug	.27
Swivel attachment plug	.12
Composition—2 Pc. Plug—Composition	0.8½

RUBBER-COVERED COPPER WIRE—Per 1000 ft. f. o b. New York,

No.	Solid Single Braid	Solid Double Braid	Stranded, Double Braid	Duplex
14	$ 6.90	$7.30	$11.20	$17.80
12	9.20	12.40	13 75	23.40
10	12.50	16.00	17.40	30.10
8	17.60	21.30	22.75	39.40
6	.....	.....	33.00	.....
4	.....	.....	45.10	.....
2	.....	.....	64 50	.....
1	.....	.....	83.50	.....
0	.....	.....	114.00	.....
00	.....	.....	133.40	.....
000	.....	.....	162.80	.....
0000	.....	.....	193.00	.....

SOCKETS, BRASS SHELL—

½ In. or Pendant Cap Key Each	Keyless Each	Pull Each	¾ In. Cap Key Each	Keyless Each	Pull Each
$0.33	$0.30	$0.55	$0.39	$0.36	$0.61

Less 1-5th standard package	25%
1-5th to standard package	32%
Standard package	37%

WIRING SUPPLIES—

Friction tape, ¾ in., less 100 lb. 34c. lb., 100 lb. lots	33c. lb.
Rubber tape, ¾ in., less 100 lb. 34c. lb., 100 lb. lots	33c. lb.
Wire solder, less 100 lb. 27c. lb., 100 lb. lots	29c. lb.
Soldering paste, 2 oz. cans	$1.00 doz.

ENCLOSED SWITCHES, KNIFE—Safety type, externally operated, 250 d.c. or a.c., N E.C.

TYPE "C" FUSED BOTTOM

Size, Amp.	Double Pole, Each	Three Pole, Each	Four Pole, Each
30	$4.50	$6.00	$7.25
60	7.50	8.25	10.50
100	10.50	13.00	22.50
200	16.00	20.00	36.00

Discounts:	
Less than $25.00 list value	30%
$25 to $50 list value	30–5%
$50 list value or over	35%